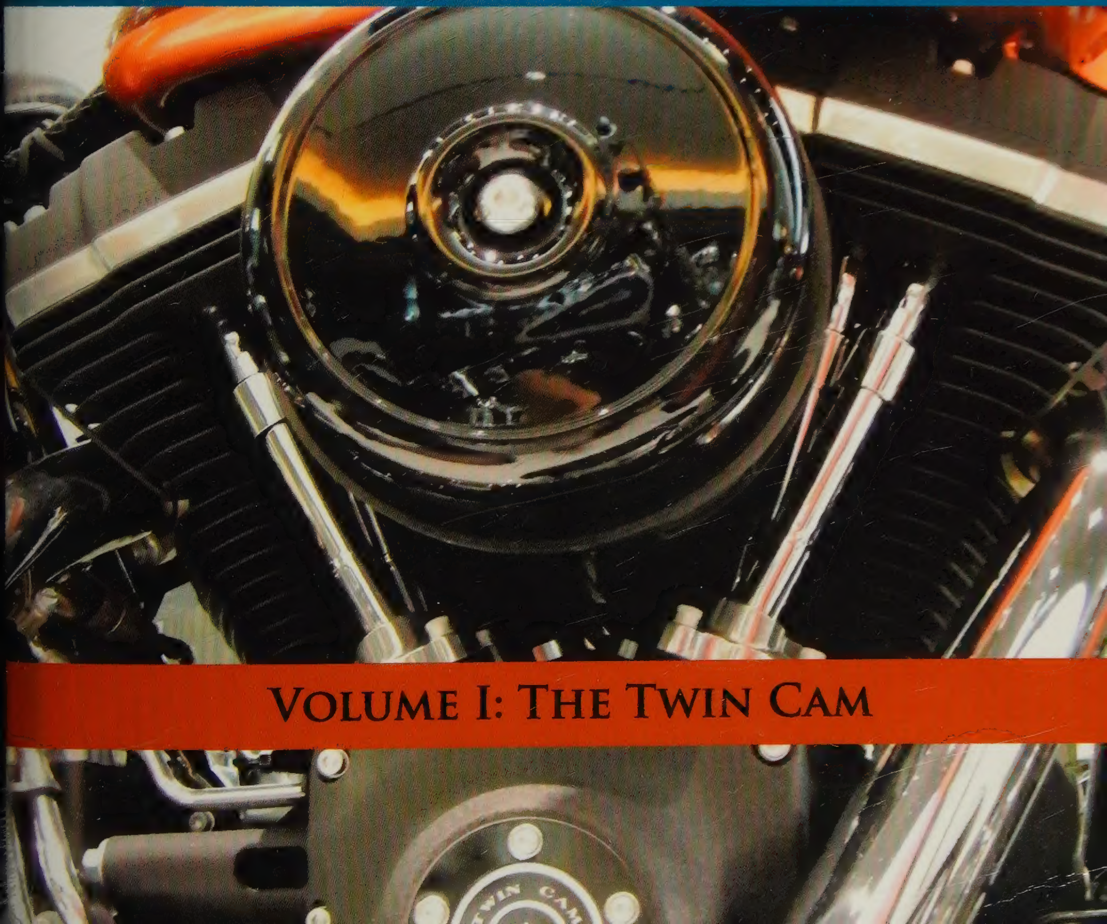
DONNY PETERSEN

"AS A BIKER, RIDER, MECHANIC, BUILDER, OR ENTHUSIAST—
LISTEN TO THIS GUY. LEARN FROM THIS MAN. MAKE THINGS BETTER."
—BERT BAKER, BAKER DRIVETRAIN

DONNY'S UNAUTHORIZED TECHNICAL GUIDE

TO HARLEY-DAVIDSON, 1936 TO PRESENT



VOLUME I: THE TWIN CAM

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Donny's Unauthorized Technical Guide to Harley-Davidson, 1936 to Present

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Volume I: The Twin Cam

Donny Petersen

iUniverse, Inc.
Bloomington

Donny's Unauthorized
Technical Guide to Harley-Davidson,
1936-Present

Volume I: The Twin Cam

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ISBN: 978-1-4502-6770-0 (pbk)
ISBN: 978-1-4502-6772-4 (ebk)
ISBN: 978-1-4502-6771-7 (hbk)

Library of Congress Control Number: 2010916855

Printed in the United States of America

iUniverse rev. date: 1/11/11

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King, Road Tech, Roadster, Rocker, Screamin' Eagle, Softail, Sport Glide, Sportster, Sport Glide, Springer Softail, Street Bob, Street Glide, Sturgis, Super Glide, TechLink, T-Sport, Tour Pak, Tour Glide, Twin Cam, Twin Cam 88, Twin Cam 88A, Twin Cam 88B, TC88, TC88A, TC88B, Twin Cam 96, Twin Cam 96A, Twin Cam 96B, TC96, TC96A, TC96B, Ultra, Ultra Classic, and Wide Glide are registered trademarks of Harley-Davidson, Inc., Milwaukee, Wisconsin, USA or Harley-Davidson Motor Company. The words: Bad Boy, Blast, Convertible, Deuce, Duo-Glide, Firebolt, Hydra-Glide, Revolution, Thunderbolt, Tri Glide, V2, V-Fire III, V-Rod, XR1200, and XR1200X are trademarks of Harley-Davidson, Inc., Milwaukee, Wisconsin, USA, or Harley-Davidson Motor Company. The following model designations and any derivatives thereof for Harley-Davidson motorcycles are used in this book for reference only: EL, FL, FLH, FLHC, FLHF, FLHR, FLHRC, FLHRI, FLHRCI, FLHS, FLHT, FLHTC, FLHTCI, FLHTCU, FLHTCUI, FLHTCUTG, FLHTK, FLHX, FLHXXX, FLST, FLSTC, FLSTCI, FLSTF, FLSTFI, FLSTN, FLSTNI, FLSTS, FLSTSB, FLSTSCI, FLSTSI, FLT, FLTC, FLTCU, FLTCUI, FLTR, FLTRI, FLTRX, FX, FXB, FXCW, FXCWC, FXD, FXD35, FXDB, FXDBI, FXDC, FXDCI, FXDF, FXDI, FXDG, FXDL, FXDLI, FXDS, FXDS-Conv., FXDWG, FXDWGI, FXDX, FXDXI, FXDXT, FXE, FXEF, FXLR, FXR, FXRC, FXRD, FXRDG, FXRP, FXRS, FXRSE, FXRS-Convertible, FXRS-SP, FXRT, FXS, FXSB, FXST, FXSTB, FXSTBI, FXSTC, FXSTD, FXSTDI, FXSTI, FXSTS, FXSTSB, FXSTSI, FXWG, GE, K, KH, VRSC, VRSCA, VRSCB, VRSCD, VRSCDA, VRSCF, VRSCR, VRSCAW, VRSCAWA, VRSCW, VRSCDX, VRSCDXA, WL, WLA, XL, XL883C, XL883L, XL883N, XL883R, XL1200C, XL1200L, XL1200N, XL1200S, XLCH, XLCR, XLH, XLH883, XLH1100, XLH1200, XLR, XLS, XLT, XLX, XLX-61, XR-1000, XR1200, and XR1200X plus any of the above that form part of the Screamin' Eagle CVO models that will have the suffix SE or the plethora of police models that will generally contain the letter P in the model designation nomenclature. In addition, there may be other derivative models that base or bear reference to FL, FLH, FLHT, FX, FXST, FLST, FXR, FXD, VRS, XL, and XR.

E. & O. E.

Acknowledgements

Firstly, my parents deserve the greatest credit. Value systems instilled in the formative years carry one through life.

After the Nazi invasion of Denmark, my parents' homeland, they both served honorably in the Royal Canadian Air Force, emerging as officers at war's end. I thank them for the many sacrifices they made defending freedom for future generations. Their wartime experiences inspired me never to start a fight but always finish one, no matter the consequences. They worked unselfishly at multiple menial jobs, day and night, so I could get an education in their new homeland, Canada. They taught me to work hard, to be honest, and to treat people, as you would have them treat you, never to hate, as negative energy will destroy oneself from within. Their teachings and love have held me in good stead my whole life.

The schoolyard is a cruel instructor for those who are different; it teaches prejudice, fighting, and the gang mentality no matter the social class. One learns to either fight or become subjugated. How one rises above this tribalism dictates a person's ability to successfully deal with life's problems. How one learns to deal with problems determines the quality of one's life.

The educational system perpetrates and imposes unjust values on the young mind, favoring some and discriminating against others. Examples are IQ testing that does not recognize cultural differences, ill-educated parents, or the use of English as a second language. The educational system teaches the poor that they are intrinsically bad and will never achieve any of education's goals; yet one can survive all of this and excel. I quit school on my own terms when I realized I could be anything I wanted and that I could pass all my examinations. I finally overcame artificially instilled inadequacies, realizing how spurious the system is. Everything hinges on and reduces to a piece of paper.

I thank the dealer nicknamed "Mouldy" who sold me my second Harley back in 1969 with no oil in it. He blamed it on me, not realizing I did not even know how to check the oil. Mouldy was the only game in town. Many times when I bought parts from Mouldy he would say, "I only have two in stock so you can't have it. I always keep one for the police; I keep the second for my best customers. Don, you can have the third if I have it!" We used to watch him go to the hardware store to buy common nuts, bolts, cotter pins, etc. He would stand at his parts counter putting the hardware into Harley boxes right before our eyes. He would then sell these penny purchases for dollar H-D prices. Mouldy was instrumental in my decision to learn Harley mechanics and work on my own.

The horrific motorcycle accident that left me unable to move for many months, living daily with the impending threat of paralysis, and refusing amputation were probably my best experiences. They developed a steely resolve because there were only two choices…go crazy or be strong. Adversity leads to opportunity. I acknowledge the doctors who told me daily that I would never walk again; their negativity inspired me to become a weight lifter, to climb Mount Kilimanjaro, and to attempt Everest.

Death on Everest was one of my most excellent experiences. Inner strength and the refusal to give up carried me through. I even managed to save another climber, undeserving as he was since he begged me to leave him behind to die. I thank wife number three, Elizabeth, who was instrumental to my survival, although she threatened to kill me for bringing her to that godforsaken mountain.

Lenny Creed, publisher of *Canadian Biker* who gave me my first opportunity in 1989 as tech writer with my first monthly column, The Dept. of Acceleration. Our relationship benefited us both, as the magazine grew more popular through our mutual efforts. Lenny and I are cut from the same cloth.

Buzz Kanter and Chris Maida, publisher and editor respectively of *American Iron Magazine,* have given me free rein writing Techline, allowing me to develop into what I am. When approached by Canadian authorities, they would not fire me for being who I am.

Marty MacDougall, my Canadian East Coast buddy, allowed exposure of my business worldwide through his photography of the bikes Heavy Duty Cycles built over 30 years. It allowed our being featured in every major Harley-oriented magazine in the world.

My pal Gareth Seltzer is the selfless, consummate champion of the underdog…like who gets away with a name like Gareth in the biker world? Well, he does because everyone of worth likes him. This adventurous blueblood uses his considerable intellect, social networking, wealth, and energy to help those that would help themselves. Gareth gave me the opportunity to piss into the wind one more time in addressing the Empire Club's prestigious forum to help advance biker civil rights. He also came to my rescue in 2007 to obtain my release on bail rather than wait in an overcrowded and repressive jail cell for 3 ½ years before my onerous 5-month trial could begin.

I acknowledge the efforts of certain media, politicians, and authorities who have systematically prevented me from teaching, designing mechanical curricula, and writing licensing examinations, all of which the Ontario, Canada Ministry of Education and the Superior Court recognized that I preformed with skill, honesty, and integrity. These crusaders for their version of good are currently trying to have sponsors and television stations prevent me from appearing in my television show segments.

I thank the producer of my TV show for hanging tough when it would be easier to get rid of me. Of course, after blond hair and big tits, I am the most popular segment of the show. Oops, spoke too soon. He, too, has succumbed to authoritarian pressure. All of this because of my lifelong sequential memberships in two prominent motorcycle clubs.

I thank my pal Guy who does hang tough when the going gets tough.

I have been planning forever to write this series of books along with a sequel to the movie *Easy Rider.* I never had time with all my endeavors, particularly with the educational system. I now make time because of the authorities' ongoing and systematic denial of every previous course of creative endeavor. They cannot take my writing from me.

Preface

First, some kind words from Chris Maida.

As the editor of *American Iron Magazine*, I have known and worked with Donny Petersen for over 11 years. To this day, the depth of his knowledge of Harley-Davidson's, both old and new, is still astounding to me. I have been riding and wrenching for almost 40 years. During that time, I have met lots of knowledgeable mechanics, designers, builders, and engineers. Moreover, in my opinion, Donny ranks up there with the best of them in knowledge and experience. – Chris Maida, editor, American Iron Magazine

Donny's Unauthorized Technical Guide to Harley-Davidson, 1936 to Present will be comprised of the twelve volumes listed below. I will cover all the traditional Harley-Davidson models from 1936 to present except for briefly foraging back to 1929 when the V-Twin 45^0 Flatheads introduced before I do the theoretical and practical volumes. A brief synopsis follows for the reader's perusal.

I. *The Twin Cam* (published) [1]
II. *Performancing the Twin Cam* (published)
III. *The Evolution: 1984 to 2000* (published)
IV. *Performancing the Evolution*
V. *The Sportster: 1952-to Present*
VI. *The Shovelhead: 1966 to 1985*
VII. *Panheads, Knuckleheads, and Flatheads: 1929 to 1973*
VIII. *How It All Works*
IX. *Lubrication*
X. *The H-D Technical Encyclopedia*
XI. *Tech Tips*
XII. *Living the Dream*

Each volume will describe, discuss, and analyze a different technical subject within the world of Harley-Davidson except *Living the Dream*, which will be about my riding exotic locales and the Rode-Mode survival tips I learned the hard way.

Volume I: *The Twin Cam* is the comprehensive first book that will lay the groundwork for all that follows in *Donny's Unauthorized Technical Guide to Harley- Davidson 1936 to Present.*

[1] Volume I has two versions; the original covers from 1999 to 2008 and is 430 pages while this the updated Volume I is over 700 pages with smaller type and covers until 2012. These volumes are available through *amazon.com* or *iuniverse.com.*

Volume II: *Performancing the Twin Cam* will be a dynamic introduction to the quest for speed. The Twin Cam is the best platform for performance in the world of Harley.

Carburetors, fuel injection, cams, headwork, strokers, big-bore, supercharging, turbo charging, and nitrous oxide are all hot topics for discussion. I will take the reader through building a very reliable 124-cubic-inch engine using stock Twin Cam engine cases, a feat no previous H-D engine has managed to perform. This volume in excess of 700 pages is available through *amazon.com* or *iuniverse.com.*

Volume III: *The Evolution: 1984 to 2000* is the bike that many credit with saving Harley- Davidson from bankruptcy. Who saved the Hog's bacon? Why did it become the chosen one? How did H-D become the darling of American capitalism? After all, there was a more progressive and practical bike in the works. However, Harley-Davidson is not about practicality.

I will explore the Evolution from different perspectives, explaining why it's so much faster and more reliable than its Shovelhead predecessor is. However, there is a lot wrong with the Evo that loyal riders love to overlook. I will get my hands dirty demonstrating the many foibles of the Evo. This super-sized volume in excess of 700 pages is available through *amazon.com* or *iuniverse.com.*

Volume IV: *Performancing the Evolution* will describe the hop-ups available for the fastest of the Harley Big Twins up until 1999. It's easy to make the Evo faster within the limitations of the engine and retain reliability. I will explain how and show you what to do, and perhaps more importantly, what not to do.

Volume V: *The Sportster: 1952-to-Present* will begin with Flathead K models and lead into the birth of the modern Milwaukee Vibrator, the 1957 overhead-valve Sportster. The Sportster lost its "vibrator" status in 2004, entering a new era of touring capability. I will chronicle the Sportsters many mechanical changes over the years.

The historically ignorant and sexist derisively relegate the Sportster to *girl's bike* status. Originally, a man's bike, the Sportster dominated racing as well as the hardcore outlaw lifestyle that all modern riding clubs like HOG are based on. Consequently, it is the most customized Harley of all time. Performancing this ground pounder will be a hot section of the book.

I will then explain the future and all the changes that will occur to meet new 2015 dictates after the implementation of the 2010 Environmental Protection Agency (EPA) emissions restraints. There will be big changes in the Sportster to meet compliance, beginning with electronic fuel injection for all models in 2007.

Volume VI: *The Shovelhead: 1966 to 1985* will discuss their development from the Panhead. The Shovel lost our affection with the advent of its more reliable successor, the Evolution.

The Shovelhead is back with a vengeance feeding the "bobber" boom the custom industry is currently enjoying. The Shovel has become one cool bike.

Volume VII: *Panheads, Knuckleheads, and Flatheads: 1929 to 1973* will chronicle the development of the Flatheads from 1929 to the demise of the pie-wagon trike in 1973.

Next, I'll discuss the first hemi-head Harley, the legendary cast-iron Knucklehead built from 1936 to 1947.

This intriguing volume will round out with exploring the beloved 1948 to 1965 Panhead. To quote the sexist vernacular of the day, "It takes a man to ride a Pan"

Volume VIII: *How It All Works* will be a techie dream. I will explain the component parts of the engine and subsequent Powertrain from valve springs to sprockets, examining their individual functions and interrelationships. A total knowledge of the V-Twin engine will evolve in the reader's mind. With this understanding, analysis will follow and thus the ability to diagnose.

Volume IX: *Lubrication* is the all-time favorite subject of those that discuss their bikes and mechanics. Which brand oil is the best? The half-truths, marketing claims, and mythology surrounding oil are a maze that few penetrate. I am going to remove the hype and give the real deal.

Which oil will win? The combatants will be "out of the ground" fossil oil versus manmade synthetics. Myth will separate from fact, perhaps giving the reader his first unbiased look at this intriguing subject.

I will then go in depth with Harley's "marking their spot." Why do traditional oil leaks occur? How do we fix them? Why does your Harley puke oil out the breather? I will explain what is wrong and why and then explain the fixes.

Volume X: *The H-D Technical Encyclopedia* will be a calculation reference bible. There will be a comprehensive section on engine formulae that will cover calculations of every aspect of Harley-Davidson mechanics and performance. This will follow with explanations on how to make them work for you. The book will discuss such topics as taking everyday practical engine formulae like calculating compression ratios, explaining the math, and then applying the results to bump an engine's compression.

I will also discuss a myriad of interesting topics like calculating cubic-inch displacements, transmission gear ratios, and final drive ratios. The reader will learn how–just like the experts–to modify his particular bike's specifications, altering them to tailor his specific needs and wants.

Volume XI: *Tech Tips* will offer hundreds of practical tips on Harley-Davidson mechanics, short cuts, roadside repairs, and general information that will be intriguing for gear heads and casual readers alike.

One of yesteryears tips concerns a roadside fix using Comet cleanser to prevent engines from smoking oil out the exhaust. Blowing this fine abrasive into the carburetor throat reseats worn-out piston rings. This treatment stops smoke emanating from the exhaust pipes and, more importantly, prevents the spark plug from oil fouling, leaving the rider at the side of the road.

This volume will read like Confucius's sayings.

Volume XII: *Living the Dream* will contain roadside technical advice interspersed with my biking adventures. Sprinkled throughout will be Rode-Mode practical guidance that every high-miler learns the hard way, such as surviving impacts at speed with dogs as well as bears, cows, deer, moose, and a flock of Canadian geese. My riding friends and I have encountered them all.

Living the Dream will chronicle my rides around the world from crisscrossing Europe and North America to Central America and Brazil. The riveting circular ride around South Africa to God's Window is in a most beautiful and friendly place. However, there are ten different ways to die each day.

Introduction

While studying town planning at Toronto's York University in the late sixties and early seventies, I found that I enjoyed writing essays and materials for thesis studies. At the time, I considered these years a necessary waste. *Necessary* since a diploma appeared to be a prerequisite key to a successful career. A waste because the subject matter never seemed relevant to my life. I quit one subject short of my degree. I finished that course in economics but could not be bothered to write the final exam. I may do this at some point. Economics seemed ethereal and useless. Did I leave out boring?

However, today, I find economics fascinating as I watch my stock portfolio. This subject that I now absorb with great interest also lets me analyze the modern success and failure story of American capitalism, Harley-Davidson. One needs to know economics if one wants to understand the rationale for Harley-Davidson's decision-making processes that many times contravenes analytical thought on mechanics.

One by-product of a college education is mastering the fine art of bullshitting, also known as *taking a position.* This was actually the main reason I quit since this seemed so phony and thereby tainted the otherwise good aspects of an education. Taking a position returns to haunt me today as prosecutors define my life by their persecutory tainted thoughts in an adversarial court system that leaves much to be desired. Judge not until you too have been through the justice grinder! This relentless steamroller makes bad mistakes in both opposing directions.

The hippie influences of the early days made sociology and psychology interesting subjects since we had an innate need to understand where society had gone wrong. Even though a lot of that stuff turned out to be garbage, it does help me understand the third factor after economics and sociology and influencing every Harley- Davidson corporate decision: the psyche of the Harley rider whose needs range from reliving a romanticized past to the Freudian concept of an extension to the male...well, I am sure the reader gets my drift. I say this half in jest, true as it is, as I too, have had a need to ride a Harley-Davidson my whole life.

Little did I know that physics, the most difficult and boring of subjects, would, decades later, resurface in my mind, allowing me to analyze engine dynamics? Physics explains mechanical problems and, more importantly, the solutions.

Sociology explains the modern success story of H-D and, again, the reasons for corporate decisions relating to consumer needs.

College (University in Canada) prepared me in a unique way for the knowledge I would need decades later in a blue-collar world.

I quit school to become a Harley mechanic without having the benefit of any technical background whatsoever. My mother would not let me take those courses because I might join a gang. Authorities say I have been a gang member for close to forty years now. We in the biker world call them clubs. I am a club member.

Many times in life, I do things backwards. In 1971, after a local dealer ripped me off, I opened a repair shop in Toronto that later became Heavy Duty Cycles. I did this before I became a licensed mechanic in 1977. I loved working on my 1966 Shovelhead, my 1938 Flathead 80, and a 1954 750cc K Sportster as well as my friends Pans, Knucks, and Flatheads. I learned fast, absorbing mechanical knowledge like a sponge. Soon I realized that I had skills other mechanics seemed to lack.

I understood why the Harley factory turned out bikes the way it did because of those formerly useless subjects I once spurned. I understood the needs and wants of the Harley rider. More importantly, I developed diagnostic skills because I could understand the processes causing mechanical problems. I understood venting gases, vacuum blockages, and all the other stuff that happens inside an engine because I understood physics.

Twenty-five years later, I thanked my mother for being so persistent in ensuring that I continued my education. I had studied these dumb subjects so as not to disappoint her.

College taught me how to write and, more importantly, think. Any great wrench thinks his or her way through a mechanical problem. Too many mechanics or especially technicians simply replace parts until a problem disappears. The thinking mechanic/technician is always the best mechanic.

I spent so many years in school that I learned how to pass examinations without necessarily knowing the correct answers. I somewhat knew, but not really, Harley mechanical work but certainly had no clue about Japanese, English, or other European bikes whatsoever. I knew how to adjust a chain but knew nothing of belts or shaft drives. Fast Eddie, the head Harley mechanic in the dealership that ripped me off, sponsored me to take the mechanical examination for licensing in the trade. I passed a poorly written examination because I analyzed the questions and not because of any extensive mechanical knowledge.

I have never felt good about this. Years later, I began to teach, for the Canadian Province of Ontario, apprentice mechanics, some traveling up to 1,000 miles for the opportunity.

I knew how to analyze examination questions that would lead to a correct answer. The Canadian Federal Government put me through a course on how to write an effective examination. Now I could write questions that even I could not answer correctly without appropriate knowledge. I taught the apprentice mechanics the knowledge necessary to pass the examinations I wrote. My examinations required the knowledge of a mechanic ready to enter the trade.

The Minister of Education then appointed me to a special committee to further the skill of aspiring mechanics in motive small engine trades. From this came the rewriting and updating of course requirements.

Then we had to upgrade the teachers who were living in the past and not improving their present skills, never mind the future. We briefly taught points-condenser mechanical ignitions instead of dwelling on them as if they were the only ignition available. We concentrated on electronic ignitions, sensors, and engine management systems that barely received mention before because the older teachers did not understand this subject themselves. Yes, we taught carburetion thoroughly but concentrated more on electronic fuel injection with open and closed loop systems and diagnostic procedures.

I taught young people the future, not the past.

Writing an extensive computer-generated examination bank became my next task. The question bank, still in use today, spits out a different exam each time with correct subject-weighted questions. It matters not if the examination bank falls into student hands; the bank of questions is so extensive that only a thorough knowledge of motorcycle mechanics would enable the student to pass.

I began writing monthly technical columns first for *Canadian Biker Magazine*'s Dept. of Acceleration beginning in 1989 and then, starting in 1992, Techline for *American Iron Magazine* (*AIM*). I still write monthly for *AIM* and thoroughly enjoy it.

Around eight years ago, I started doing the Tech-Talk segment of Biker TV shown across Canada.

I always knew I would write books and now the time has come. I thought it would be a simple matter of sewing my hundreds of columns together. When I am wrong, I am really wrong. It has turned out that the books will supply the columns. Even with extensive knowledge, I found myself taking my 2007 Harley apart to see the new changes for myself.

My first book is all about the Twin Cam engine introduced back in 1999. The 2007 Twin Cam has instituted many changes, including the first serious attempt by the Factory (H-D's nickname, used by some Harley buffs), to resolve the timing compartment problems plaguing this best of all H-D Big Twin engines made since 1999. Chapters III and XII chronicle all these changes including the increased cubic-inch displacement of the engine.

The temperature will rise as the very controversial 6-speed transmission undergoes examination and detailed explanation. Chapter X is devoted entirely to the 6-speed, its successes and its problems, along with aftermarket solutions. The six-speed transmission in all 2007 Twin Cams initially tested in the 2006 Dyna models is something the aftermarket has been providing for ten years. Harley wanted to both cut the aftermarket out of H-D's action and to resolve gear noise violating new EPA decibel dictates. Preliminary reports indicate that the Factory may have failed on both counts. However, the transmission gear ratios have been coordinated with the primary and final drive ratios to produce the most seamless, integrated riding ever.

This first volume begins describing my secrecy agreement with Harley-Davidson over the then hush-hush Twin Cam engine starting with my entertaining cab ride to the top-secret section of Harley-Davidson's Juneau Avenue complex in Milwaukee. As part of an *AIM* team, I spent almost a week in March 1998 as a guest of Harley- Davidson. In total secrecy, the Twin Cams design engineers taught us about every aspect of this new model.

On a subsequent invitational trip in 1999, I was part of another *AIM* team that rode and evaluated the Twin Cams for Harley-Davidson through four states out of the York Pennsylvania facility. I was fortunate enough to be able to look at the Twin Cam development and implementation from every angle.

The Heavy Duty Cycles Toronto team, including myself, has worked on customer and personal Twin Cams six days a week since then. Because of all this, I am able to relay to you the tremendous improvements guaranteeing the continuation of Harley-Davidson's success story. You will learn from my hopefully entertaining writing style all one could ever want or need to know about this new engine. My encyclopedic knowledge about motorcycles...if I may be so immodest...will leave no stone unturned.

Volume I: *The Twin Cam* explains this engine as the most radical departure from the past since the introduction of the Knucklehead in 1936. First, I will delve into all the initial teething problems, then detail how the Factory attempted to resolve them. Then I will dissect the ongoing timing chest boondoggles and discuss the permanent fix in detail.

Even the Twin Cam is not immune to *marking its spot* so oil escaping the engine will be a big topic. Exposing the culprits overloading the breathing system and curing this malady will be an even bigger subject.

Many of the newly designed parts like the exemplary gasketing will receive their due attention.

After that, I will take up the deficient air flow in the best...however restrictive...of all Harley head designs. Then I will demonstrate how to massage these heads through porting and polishing to increase the flow of air. I will do the same with the new TC96 heads introduced in 2007.

For those that want to retrofit the new engine into older frames, there will be a complete how-to chapter on this subject.

Then, I will dissect all the new changes like the new 2007 TC96 engine, super sized Drivetrain, the 2008 ABS braking, electronic throttle control Furthermore, I will do the same for the 2009 models discussing such topics as the new FLHT frame to accommodate larger engines, CVO 110 improvements, the overdue rubbermount 4-point engine-powertrain mounting system, dramatic new wheel and tire changes plus the first H-D trike since 1973, the FLHTCUTG Tri-Glide.

Are the improvements, well, improvements? Why is there not much of a horsepower increase despite eight more cubic inches? We shall see but it is looking good.

I will do the same with the 2010 and 2011 models exploring the new exhaust catalyst and the necessary changes surrounding this new feature that meets the midyear 2010 EPA mandates as well as the many other changes that occur this year after the ravages of the Great Recession begin to affect the Motor Company in a big way.

I will then decipher Twin Cam serial numbers and the necessary Vehicle Identification Numbers. Big changes occur in 2010. H-D has grown so much that a new part numbering system institutes in December of 2009. I take the confusion away from the numbers so that they can become your friend.

Lastly, I will trace Harley-Davidson history from its most difficult beginning under new management during the Deep Recession of 1982 to the very real struggles the Motor Company faces in the Great Recession of 2007 to 2009.

This all-embracing first volume will lay the foundation for all that follows in *Donny's Unauthorized Technical Guide to Harley-Davidson, 1936 to Present.*

Please enjoy.

CHAPTER I

March 1998: Introduction of the Twin Cam

The Secrecy Agreement

In March 1998, Harley-Davidson invited me to Milwaukee along with Buzz Kanter and Chris Maida of *American Iron Magazine.* We some of the first outsiders were to join the select few who planned, designed, and implemented the Twin Cam 88. Our mission was to learn every facet possible about this new motorcycle and in turn teach the riding public through our writing. The following is written from a 1998 perspective.

Up to seven engineers taught us about the new motor for four days from 6:30 a.m. to 11 p.m.

Under secrecy agreements with Harley-Davidson, I was unable to talk about this honor until June 25, 1998. *American Iron Magazine* published my extensive articles on the Twin Cam 88 in its August 1998 issue thus introducing the world to the new engine.

Ya'll Ain't Gitten in der Boy! Dats were da secret stuff is.

The cabby asked. "Where ya'll going, boy."

"Juneau Ave, 3700 West Juneau Ave." I said.

"Wastin' yer time, boy." He admonished. "Ya'll ain't gitten in der. Dats were dey do dat secret stuff"

"You mean research and development?" I volunteered.

"Ain't dat what I said boy! I will wait here. Got me a two-way trip, cuz you ain't gitten in."

The old six-story building at 3700 West Juneau Ave. in Milwaukee looks exactly what it is, a pre World War II factory. It now houses H-D's corporate offices, normal and secret storage, and Harley-Davidson Archives.

The modern Milwaukee factories are located on Pilgrim Road, which normally does not offer tours and the Capitol Drive Plant that does have public tours. It has a little Harley store, which has exclusive souvenirs only available there.

Out front of the Juneau facility is a Harley's only parking lot with a "No Cages Allowed" sign. Surrounding this primo parking area are the less desirable parking areas for the cages (cars).

The security in the lobby inside was strict.

Enclosed in protective glass was a 1903 Harley-Davidson. It was gussied up to look better than it did back then. Its single-cylinder 3 HP belt-driven engine with no transmission contrasted greatly with the 95th anniversary Road King in the opposite corner.

After this article was published in *American Iron Magazine,* Dr. Martin Rosenblum, the official Harley-Davidson historian wrote a letter to *AIM* asserting that I was incorrect and that the 1903 Harley was indeed totally original and identical to when manufactured. The Letters column of *AIM* published his letter and my reply in the November 1998 issue on page fourteen. Dr. Rosemblum wrote, "Thank you for the wonderful piece you wrote entitled "Security at Juneau Ave." However, you made a serious error in referring to our 1903-04 Harley-Davidson as a "replica." It is not. It is the real thing. Please inform your readers that we have Serial Number One in our lobby for the world to see just as it rolled out of the original factory."

Dr. Martin Jack Rosenblum
Harley-Davidson Archives Historian

Donny's reply:

I wrote "1903 Harley-Davidson that's been gussied up to look better than it did back then." I could tell the bike wasn't a replica but I commented to a factory worker who was conducting a tour that it sure was pretty. It was obviously nicer looking than it was in 1903. He laughed and said, "It sure is."

Donny Petersen. [1]

We disagree but Dr. Rosenblum is an authority on Harley-Davidson and did a wonderful job historically documenting the history of this venerable company.

Harley-Davidson Secrecy and Security

Returning to the lobby, opposite the 1903 H.D., the Harley emblazoned black leather furniture sat in the third corner nearest the door outside. A security guard sat at the front door beside the enclosed black check-in counter. Above him in orange neon was the Bar and Shield, Harley's symbol.

After I identified myself, the secretary phoned the magic name I proffered and all of a sudden, I was okay. "Wait for security. Sign in this book, wear this security tag while in the building, and turn it in when leaving." Cameras were prohibited. "You must agree to random searches at any time. In addition, the legal department requires signing a confidentiality agreement. You are not allowed to discuss anything you see until June 25th." The date was March 18, 1998.

Do you have any idea how hard it was not to discuss the Twin Cam Fathead for three whole months while all the people supposedly in the know give opinions about what the Factory was doing?

H-D's top engineers taught us over the best part of a week. We have held each individual part in our hands, seen the completed engine and assembled Fathead bikes.

It was tough especially when the rumors for the most part were wrong. I bit my lip more than once. Having delicious secrets was no fun.

Why did they choose me? I never thought the Factory would approve me in the first place since I was not shy when it comes to being critical in my columns. However, the Factory said I was okay. I am aftermarket and definitely not a yes-man. However, I feel that I am diligent in attempting to be fair. The body language was already telling me the Factory people were confident that they had a winner.

I was not so sure. I had my list of structural complaints about the predecessor Evolution engine. Resolve the whole list with improvements in the new engine and you have a convert.

The critic in me becomes loud and clear if this does not happen. The H-D fan in me laps on the praise when it does happen.

Boxes, purses, and bags are searched going in and out. As I wrote this, waiting for my escort to be like Velcro on my side, a security glared at me, officiously wondering what I was writing. Suddenly, I was off the hook as the guard was busy searching a briefcase of someone wanting to leave.

Weather had delayed my cohorts Chris Maida and Buzz Kanter in Chicago. Therefore, I found myself with a nervous Steve Peihl who was in charge of the press. He was great at keeping a secret and not so good at letting one out.

The elevators were the old style, pull-down-the-wooden-slat-door freight ones. We walked through a maze to get where we are going, which turned out to be the Harley-Davidson Archives. The door to the archives is always locked. It is necessary to bang on the door to get in and ask permission to get out.

The Archives

What a strange place to be viewing the future. "How come here?" I asked. "No one will suspect here," came the logical reply. Dr. Rosenblum, the fastidious H-D historian, didn't like this violation of his inner sanctum, but he consoled himself by watching history in the making. Once allowed inside, I immediately discerned the reasons for security and secrecy.

There it was…a mechanic's dream. About 460 foreign-looking but somehow familiar parts lay in front of me, I easily identified maybe fifteen or twenty as being 1984-to-present Evolution motor parts. To the side was the complete Twin Cam Fathead engine while on the other was a 1999 Dyna Twin Cam motorcycle.

I was ecstatic as the group lead by "Skip" Metz began educating me. When realizing my teachers were the engineers in charge of design, testing, and production, I was in heaven. Leading the team was Bill Davidson himself who was extremely emotional about this new milestone for Harley-Davidson. His grandfather must have felt the same way in 1936 when he introduced the new overhead valve Knucklehead that replaced the old Flathead side valve technology.

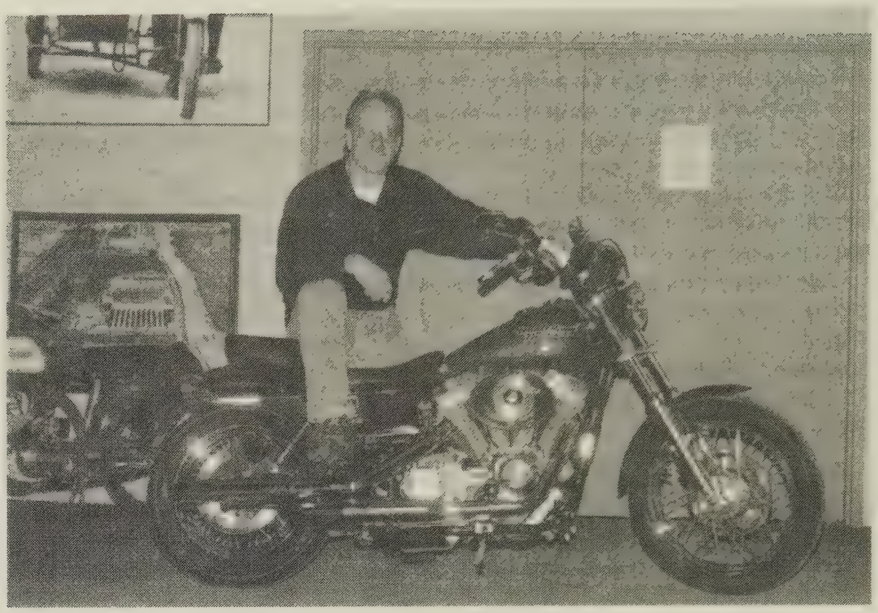
The Washroom

By now, Buzz and Chris's plane had come in from Chicago. The engineers had to teach all over again. This was great. I sat back and listened. I was now concentrating on the mechanical theory relating to the newer technology. I began conceptualizing how everything interacted.

We needed pictures, many pictures. We gained security clearance from Steve. However, the archives were too dark for crisp, informative photos. We had to improvise somehow. Chris returned from the locked washroom across the hall. He said the light was great in there. Over we went carrying all the parts. The old-style washroom had lots of white marble, space, and big factory-style windows. We all reconvened in the washroom the next day, taking numerous pictures of each part and the subassembly it fit in.

After we relocated, poor Skip explained in detail, once again, everything about each part for the third time. I then understood every component, conceptualized how the different systems like oiling, breathing, and the spark map matrix worked. I also appreciated the noise and emissions aspects imposed by government regulations. More importantly, I grasped how they would influence the Fathead and the future.

My immediate impressions were all very favorable. This was some engine. This was a wave of the future for Harley-Davidson and it was a bright future indeed.



March 1998, Donny on a Prototype Twin Cam Dyna FXD in the Harley-Davidson Archives at 3700 West Juneau Ave., Milwaukee

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I'm posing with a prototype Dyna Twin Cam in March 1998. The location is in the hallway in front of the Harley-Davidson Archives on an upper floor of 3700 West Juneau Avenue in Milwaukee, Wisconsin. Surrounded in secrecy, we could not release information until June 25, over three months later. Inside the Archives, a disassembled Twin Cam engine was spread out before us. The designing engineers intensively taught us for three full days from early morning until late at night. Harley personnel are passionate, very committed, and work long hours.

The Fathead Name

During lunch one day in Milwaukee before the introduction of the Twin Cam, I was able to help nickname the new engine as the Fathead. Harley-Davidson never promoted this descriptive moniker. *American Iron Magazine* referred to the Twin Cam as the Fathead for many issues, using it everywhere.

I believe the reason was that we at *AIM* coincidentally came up with the H-D secret Fathead nickname. We started to use it in print before they were promotionally ready. Harley lore and tradition dictates that every engine has a nickname like the F-head, the Flathead, the Knucklehead, the Panhead, the Shovelhead, the Blockhead (Evo), and now the Fathead.

AIM editor Chris Maida, publisher Buzz Kanter, and myself, the Techline columnist since 1992, were sitting around during a break from our education on the Twin Cam 88. We were tired but constantly stimulated by the onslaught of new information swirling around us. We tossed around possible names like the Splithead because the rocker boxes split into two pieces but always came back to the Fathead. Really, what else could we call this oversized squat engine? The Fathead nomenclature based on the fatter top end on the Twin Cam 88 due to 60 percent more finning on the .250"-bigger diameter cylinders and heads. The combination of the bigger piston bore and the most massive cooling fins ever used on a Harley made this name a natural. Yeah, we could have called it something like the Bighead but the word *fat* has a special place in Harley lore because of the astronomical success of the Softail Fatboy. Arnold Swarzenegger riding a Fatboy in the movie, *the Terminator*, branded the name in the public's mind. In the wacky world of Harley-Davidson the ultimate, rebellious cool was fat, the antithesis of society's obsession with thin.

Now I was in trouble. Trev Deeley was the very influential Canadian on Harley-Davidson's board of directors. The rumor that he was a financier and a savior of Harley-Davidson during the buyout from American Machine and Foundry, renamed the AMF Company in 1971 was part of the lore surrounding the man. Deeley set me straight on my audacity in nicknaming the new engine. "You fucked everything up, Don! You and those magazine people have no right to do this!"

He was an irascible, good guy, if he liked you. His mercurial temper did not suffer fools gladly. Trevor was not crude, but he spoke plainly and was not above scowling, swearing, and raising his voice to make his point. He was a sharp pencil and Canada's most successful motorcycle importer, introducing many bikes, including Honda, to our shores.

This avid, lifelong motorcyclist would piss off his business-oriented motorcycle dealers. Before he saw these dealers, Trevor usually visited me first at Heavy Duty Cycles when he flew into Toronto from Vancouver. After all, I was the symbolic aftermarket enemy. He did not like a lot of them. He viewed many dealers as lazy, complaining, spoiled brats. It would drive him crazy that some of his people would play golf in the afternoon instead of working. Trevor used his dealer network to make money, lots of it, but the dealers were not his kind of people.

He would shoo my friendly but formidable dogs Huey, a 165-pound Great Dane, and Beau, a 115-pound Shepherd-Bouvier, out of the way, sitting down uninvited on a greasy, stained chair, and go into one of his wonderful rants. My dogs would eyeball me, then him, warily back and forth to see if I felt threatened. If so, they would take care of this blustery intruder. After awhile, they ignored Trev, because they could see how much I enjoyed his company. I will tell you one thing: His dealers never ignored him. He was on them even if they were doing everything right, which, of course, was impossible.

He would tell me that if I would quit my motorcycle club, the Para-Dice Riders...it was bad for the new H-D corporate image...he would make me a rich man. He knew I would not quit for money and he liked that.

One time he said, "How come you didn't attend my dinner roast?" It was a big ta-doo honoring him. I had heard about it but did not think I was that welcome or that he even wanted me there, not to mention it was 3,000 miles away. "Why didn't you invite me," I asked. "You need a godamn invitation?" he bellowed. He then said, "The Hells Angels came. I got restless at the head table listening to the bullshit about how great I was. They went outside so I grabbed a couple of beers and went out and hung out with them around their choppers. Told them they should not cut up a Harley that way, but you could tell they knew their way around their bikes and a wrench. Nice fellows, 'course I understand they're not always that way," he said with a mischievous wink. Trev liked them on an individual basis because they were bikers. They just were not his kind of motorcyclist.

Another time he was frustrated because he did not know how to quell dealer whining at a dealers' meeting. "What am I going to say to these complainers?" I suggested, "Where else in the world in any franchise can you become a millionaire in three years not knowing what you were doing!" He looked at me stunned. He did not say anything and the conversation drifted elsewhere. Did he ever say that? I do not know, but he was sure capable of it.

One time he said, "Do you want to be a dealer?" "Not me, man, besides I'm in a bike club and you guys won't tolerate that." "Aw, screw that, Don. Just don't sell aftermarket parts and you can have what you want." Of course, it did not matter that Trev's personal dealership sold many aftermarket parts. "I wouldn't have to Trev. H-D has many good parts coming down the line. Many of your dealers are not bikers so they don't know what the riding public wants. They don't know what to stock and what sells."

"Where would you like one?" he repeated.

"Well Trev, there's a nice spot up north in the country, but the dealer there is too greedy. He would want too much money." Trev surprised me with his answer, "That pompous pain in the ass, I've been looking to get rid of him. It's yours. No money, just show you are financially capable. There are the setup building costs and, of course, inventory. Find a good location in the area. What does he own after he loses the H-D dealer license?"

Trev was right in his assessment of that dealer, but then I a changed gears to lead into my next thought about a location. I said that I had been down to Milwaukee to view the.... "Don't say it!" Trev growled. "You signed a secrecy agreement" "Fuck, Trev, if I can't talk about it with you, then who?" "No one! It's a nice engine though, eh, Don? We are moving along good." Maybe Trev greased the way for my invitation to be one of the first to see the new engine.

"Yeah, that's why I might consider a big box store, Trev. Harley is on the right track." "Where do you want Don?" I named the location, and he accused me of having insider information. "Don, we've spent hundreds of thousands of dollars on demographic studies to show us where to put the dealerships and how far they should be apart."

"Trev, I took town planning at college and if you spent that much dough you got ripped. I can show you where to put all your stores." "None of your business," he barked. "Okay, you got it, Don, but it will require more design and setup costs. Of course, you'll have to follow the rules!" "Yeah," I retorted, "just like the burger joint. Two squirts of mustard on every one. Squirt three and you lose the franchise! Thanks, Trev, but no thanks."

He phoned me up one day, furious. "Stop calling the engine the Fathead. It is not your place. It's up to the riding public to nickname the new engine. That's the way it's always been, and that's the way it's going to be now."

"Well, Trev, I've been riding Harley's my whole life, so I got every right to call it what I want. Besides, what name would be better?"

"Stop it, Don!" "No, Trev!" He knew the answer before I replied. He got madder, but he still liked me and I liked him...quite a bit actually. He was a good old guy. When he lost his wife, it just broke his heart.

1919 to 1929: The First Twin Cam

The first twin cam Harley-Davidson was the two-cam. This year 1919 that initiated the first Flathead engine also saw the introduction of the first Twin Cam engine known as the Two Cam F-Head racer. The two-cam models continued until 1929. Like the Twin Cam, there were two camshafts with two cam-lobes each.

Does anybody remember the aftermarket 4-valve heads introduced in the Evo years with one set coming out of California and the other out of Montreal Canada via Italy? Well, two heads translate into 8-valves. These were extremely innovative aftermarket products but H-D had their own 8-valve motorcycles. The 1919 introduction year of the Two Cam F-Head 8-valve racer was a well respected machine that discontinued in 1929. Indian Motorcycles actually built the first 8-valve motorcycle, I am aware of in 1912. H-D introduced its first

8-valve in 1916, purely to combat Indian at the track. Very few were produced. No one seems to agree on how many but certainly it was under one hundred and more likely under fifty.

Let us get back to 1919 to 1929 where the two-cam engine, decades apart from the modern Twin Cam in 1999 were the fastest Big Twins of their day. For example, the 1928 JDH Two-Cam citizen model F-Head was 74.66 cubic inches, which translates into approximately 1200cc compared with the 1999 Twin Cam's 88 cubic inches (1450cc).

The JH was also a two-cam F-head model with a 61 cubic-inch engine (1000cc). The JDH had a reputation for being faster than any other vehicle on the road, whether a car or a motorcycle. These models were the culmination of marketing knowledge gained through the Factory race bikes of the early 1920s.

Like its grandson the TC88, the JDH featured larger finning on the heads and cylinders to dissipate the heat generated by more power. Both the 1928 JDH and the 1999 TC88 used a very safe 4.000"piston stroke. Engine size differences attribute to the JDH, 3 $^{7}/_{16}$" smaller piston bore relative to the TC88's larger 3 ¾" bore. Another fascinating similarity is the piston upgrading on both bikes: the TC88 going to hypereutectic design, which I explain later, and the JDH Dow-metal domed pistons.

The next generation engine the Flathead used flattop pistons similar in shape to the Twin Cam pistons.

The JDH was capable of speeds over 100 mph. It was a platform for more power with lots of room left for performance tuning. An ongoing theme of the Twin Cam 88 is that it's also a platform for bigger changes.

The best part is that a JDH, which was the premium bike of its time, cost about $380.(10). Well, we all know that is not the case with a TC88.

H-D Technical Heaven

If you are a tech freak like me, read on!

The 1999 Twin Cam 88 Fathead

The Fathead is about to change the World of Harley more than anything else since the advent of the Evo in 1984. Where should I start? Well, how about first describing this engine, 4 ½ years in the making, as a bulletproof platform for the future: designed with durability and reliability in mind. The Fathead expectation is to log a minimum one hundred thousand miles before rebuild.

I am writing this in March 1998 and as of this date, H-D already has a Twin Cam motorcycle prototype with this magic mileage, and it does not need a rebuild. Yeah, I know of all the Evos that have supposedly logged on the magic 100-grand, but lemme tell you that for every rider that has actually done that there are many more exaggerating their motorcycle's prowess. The Fathead is consistently going to do one hundred thousand miles without blinking. In fact, there are parts in that baby that will not need replacing for a few hundred thousand miles, like the pinion bearing that rivals those used in top-fuel dragsters.

By March 1998, the Factory has logged 2 million miles in testing with 12,600 hours on the dyno. This engine is over-engineered, relative to previous models. It is a superlative effort in engine design that I have never seen or had ever hoped to see in my thirty years of working on the V-Twin. It is a platform for many modifications. Furthermore, they will be extremely reliable.

It is obvious to me that Screamin' Eagle is going to attempt to take charge and control this engine's destiny in the high-performance arena.

Skeptically, I entered the room, which was full of engineers, product marketing people, and William Davidson. The raw emotion emanating from Bill Davidson was readily apparent as he and Dr. Rosenblum watched Harley history in the making.

I had my list of Evolution deficiencies, such as cracking engine cases, leaking base gaskets, oily blowby venting, pulling case studs…need I go on? What had they done to fix these inadequacies in the greatest engine produced by the Motor Company up until 1999?

Wow!

Approximately 460-component parts of the new Fathead engine were laid out on a large table for my perusal. A fully assembled engine sat to my right in its entire splendor. To my left was a 1999 Dyna Glide TC88 Fathead motorcycle. Talk about Harley heaven. Only about fifteen of the parts are the same as those used in the Evo. It took me mere minutes to throw every criticism I was about to launch out the window.

Three days of intensive training followed on the new motor from 6:30 am to 11 p.m. The teachers were Bill Davidson, engineers "Skip" Metz and "Koby" Kobylarz with "Spike" Kieffer giving the overview. Steve Piehl, "who bleeds Harley oil when cut," rode shotgun.

Kenny "Mr. Clean" Sutton was the VP in charge of building the Twin Cam engine. Demonstrating all the quality-control features, he showed us late at night how he was actually going to build the engines in the 400,000 sq-ft Pilgrim Road plant.

Jerry "Mr. Smooth" Wilke, vice president of H-D and president and CEO of Buell, ably demonstrated through his every action why Harley is successful. I was not a big Buell fan because of its departure from traditional Harley styling. Jerry's enthusiasm and instruction soon converted me to taking an objective second look.

Skip Metz, who turns a good phrase, summarized their efforts best: "Pain in the early phase of development is better than pain in the end." Explaining further, he said, "When I am at an event, I want people to come up and shake my hand, not give me a blast for some problem in their engine." [2]

An Overview of the Twin Cam 88 Fathead

Let's get some of the juicy TC88 facts.

The engine weighs in at 165lbs, which is heavier than previous models but the excess weight is coming from out-and-out quality.

1. The bore is 3 ¾" (3.750"), a hefty increase over the 3 ½" (3.500") Evolution, while the stroke decreases to 4.000" from the 4 ¼" (4.250") Evolution. This is good news. The lower stroke means more reliability because of slower piston speed. Big bore does not affect reliability but creates additional power with more cubic inches.
2. The combination allows a sustained engine speed of 5500 rpm, which is higher than any stock Harley that has gone before.
3. Compression increases for more oomph up to between 8.8:1 and 9.0:1. Previous engines went as low as 7.5 to 1 and as high as 8.5 to 1. Therefore, we have ourselves a fast machine here, but as I have already stated, it is going to be the most reliable engine ever used by the Factory.
4. Eighty-eight cubic inches translates into 1450cc.
5. Horsepower is in the low sixties, hovering around 62 HP at the rear wheel.Not much, you say! False and exaggerated claims by the horsepower brokers trying to sell their super- duper performance parts, etc. make real horsepower figures seem tame but consider this; the stock Evo probably has around 52-ponies at the rear wheel, depending on model and state of tune.

6. Torque is 86 ft-lbs for the FLHT models while 82 ft-lbs for the Dyna. Why is there a difference? The Bagger mufflers are bigger and can handle more volume. The ability to breathe more is the first principle of high-performance and engine efficiency. A comparative figure for the Evo FLHT is 78 ft-lbs.
7. Of greater importance, the torque curve repositions into the lower rpm area producing more usable power where desirable. This transient torque is addressed right off the line so the rider is going to feel power sooner than with previous models.
8. The heads even an AR (anti-reversion) step also known as tork or torque valves built into the exhaust port to create more low-end power. The anti-reversion step bounces returning spent-exhaust pulses back, preventing them from re-entering the combustion chamber.
9. Single-fire ignitions replace the relatively inefficient dual fire ignitions.
10. The CV Kehein carburetors are basically the same but with jetting to accommodate the extra cubes while the fuel injection systems have bigger injectors. The Twin Cam CV carburetor is part number 27412-99 (California jetting H-D 27415-99).
11. There are two cams side-by-side connected and driven by two *silent* cam chains.
12. As a result, the pushrods are straighter and do no angle as on earlier models.
13. Furthermore, there is *no* too-tight whining or too-loose clattering timing gears.
14. The barrels (cylinders) are shorter and thicker in construction.
15. Covers are non-load bearing, unlike most other Harley engines.
16. The oil pump is now inside the engine.
17. Jets of oil squirt up from the crankcase to the piston undersides for cooling.
18. Last, but certainly not least, are the external changes immediately noticeable such as the ultimate torque arm. The engine and tranny juxtapose together so they appear to be unit construction. No more parts flexing around as rigidity is another theme that pervades the Fathead. This translates into better handling, reliability, durability, and one tough machine.

In 1999, all the Softail models still use the Evolution engine and transmission while the Fathead will be in the FLHT touring and Dyna series. According to all that we spoke to, the Factory is not going to forget the Evo loyal followers. Me, I cannot even remember what it looks like. Harley-Davidson was very nervous about alienating its very loyal Evo followers.

As it turned out, discontinuation of the Evo occurred the following year (2000), when the Softail powertrain converted to the Twin Cam engine. I think the Factory concern melted away with consumer acceptance of the new engine.

Twin Cam Heads

Bathtub-style combustion chambers are noticeable when the engine is apart. When assembled, the fat finning for more cooling is most striking. There is a 60% increase in fin surface area. The 242 alloys are the same used in the Evo heads.

The more observant will notice the reduction to a 12mm spark plug from the traditional Big Twin 14mm. Why this reduction in plug threads dimension? Well, with the bathtubbing combustion chamber shape, there is less room between the valve seat insert and the spark plug hole. If left at 14mm, the engineers felt that it might cause a weakness. A multitude of high-grade features will be an ongoing theme in this engine.

The bathtubbing is more a rounded rectangular shape than the bathtub or kidney shaped configuration that we know from the aftermarket. For the uninitiated, I will briefly describe the different head configurations going back a half century.

1. The hemi-heads like the Shovelhead (1966 to 1985), Ironhead XL (1957 to 1985), Panheads (1948 to 1965), and Knuckleheads (1936 to 1947) have rounded hemispherical inverted combustion chambers. The piston top or dome is also rounded and upturned in order to fit into the hemi-head. This system is not very good for uninterrupted flame travel or a high percentage of burn since the piston dome interferes.
2. The Evolutions have a D-shaped combustion chamber. Inside the D, the chamber cuts off instead of continuing in a perfect circle. The rest of the circle is flat and even with the surrounding gasket surface. A flat top piston squeezes up against this flat *squish band*, squishing the air/gas mixture turbulently into the smaller D chamber promoting better flame travel and a much higher percentage of burn.
3. The TC88 Fathead's bathtub chamber is small, having only 85cc volume, which is why the compression ratio is higher at 8.8:1 and 9.0:1 compared with the Evolution 7.5:1. Bathtubbing creates a flat squish band all around the chamber so that the big 3 ¾" diameter flat-topped piston squishes the air/gas even more turbulently into the chamber from all sides, promoting the best flame travel, and highest percentage of burn of the different head configurations described.

The permanent mold head (black, 16722-99 front; 16724-99 rear) has the same size intake valve (18074-83A) as the Evo.

1. However, the exhaust valve (18085-99) is about .030" smaller in diameter but a little thicker. It is marked with an indent in its center face for easy recognition.
2. The two length pushrods (exhaust 17922-99, 10.536" long; intake 17923-99, 10.418" long) are also different colors for the same reason. The exhausts are black oxide while the intakes are silver. Pushrod angle holes are almost parallel straight up and down. Largely eliminated by the dual cams are inefficient Evolution and earlier motor pushrod angularity with their resultant problems.
3. Combining with this smaller exhaust valve is a smaller diameter, reworked exhaust port that takes advantage of Bernoulli's principle about moving the exhaust gasses exiting faster and more efficiently to help with cooling and emissions considerations. The perfect analogy is when a wide, lazy river narrows, the water rushes to get the same volume through a smaller space in the same amount of time. This action is similar to the new exhaust port, which must move exiting exhaust gases faster in order to move the same or greater volume in the same time period. The pressure of the exhaust gases behind the narrowing exhaust port push the gases to move faster in the port itself.
4. I have mentioned the built-in torque valve (1999 to 2006), more correctly called anti-reversion (AR). It is not really a traditional valve but a step in the exhaust port to help confused gases go exit the pipe. The TC96, TC103, and the CVO 110 eliminate the use of the AR valve in 2007-to-present heads and compensate with a port redesign.
5. The same exhaust pipes will fit the Twin Cam as the Evolution since the ports and the mounting studs are in the same location. The head height has not changed, although it is fatter with the 60% increase in fin surface area. There is access for ambient air to cool the exhaust port area.
6. Dual cylindrical valve springs in use from 1984 to circa-2002 (inner 18202-83; outer 18201-83); rocker arms, and rocker arm shafts have not changed from the Evolution. A single beehive valve spring (18245-02) replaces the dual cylindrical valve springs circa-2002 to present.

7. There is a new passage in each head from the rocker cover that begins with the breather (venting), apparatus (17650-99, 17650-02) located between the rocker arms to allow internal gases to exit the heads. Notice I said gases. This breather design is supposed to work well, quite unlike its Evo predecessor that sometimes allows oil, whenever the urge hits, to exit with the gasses all over the external motor. While an improvement, the new breather system also has problems separating all oil from exiting gasses especially when increasing displacement to 95c.i on the 1999 to 2006 TC88 and 103.ci on the 2007-to-present TC96. Increased displacement combining with high rpm sustained riding can overwhelm the breather system because of the increase in volume of displacing air. As the pistons descend in their respective cylinders, the air underneath must go somewhere. It travels up the pushrod tunnels into the breather for oil vapor separation and exits out into the air breather. Faster rpms over time will substantially increase the amount of air displacing by the faster moving pistons as will the swept area (displacement) they cover in a big-bore engine.

The Barrels (Cylinders)

1. The barrels also known as cylinders (16525-99 silver; 16526-99 black) are shorter due to the smaller engine stroke of 4.000" and a higher deck height on the engine crankcases.
2. Stroke is the length of piston travel inside the cylinder.
   a) The deck height is where the barrels mount to on the engine cases.
   b) The cylinder that is sold with a fitted standard piston and ring set is the same for front and rear, hence the use of only one part number.
3. The barrels are fatter due to the massive 3 ¾" bore, which is a full .250" bigger in diameter than the predecessor Evolution cylinder bore. Their shorter length combined with the increased fin area only bolsters this visual perception.
4. The cylinder sleeves that house the pistons are thick, .247" compared to the Evolution at .173". The official Factory reasoning for this ¼"-thick sleeve liner, which runs counter to some mechanical thought, is that it provides stability for the piston as it changes thrust axis particularly at the bottom of the stroke. Changing or reversing thrust axis is engineering jargon. When the piston is descending in the cylinder, it has to reverse direction at the bottom and start heading up the bore again. Because the barrels are at a 45-degree angle, the piston pushes against one side of the barrel going down, but when it changes direction, it suddenly thrusts against the opposite side.
5. The cylinder design easily accommodates a big bore of 3 ⅞". Screamin' Eagle will offer a conservative 1550cc upgrade as indicated by a thicker than necessary sleeve on the 1450cc stock cylinder bore of 3 ¾".
6. Again, the common theme of rigidity in this platform engine comes into play to provide stability for component parts. The thickness of the liner achieves this. Cast into the high-pressure, die-cast cylinder is the new spiny lock iron sleeve. Please see Volume II: Performancing the Twin Cam for an in-depth analysis of this Spinylok cylinder sleeve used in all model Twin Cams in Chapter III: *H-D 110 Cubic Inch CVO*, section, *CVO 110-Cylinders and Liner Sleeves.*

When I first viewed the engine all apart in the Factory archives, it just blew me away to see the base gasket solution and made me a convert to the Fathead.

Why didn't the Factory O-ring the barrels to prevent oil weepage from the base, I was about to demand.

1. Furthermore, why not use the barrel-locating dowel pin as a hollow oil passage for returning top end oil, which would correct another Evolution engine bugaboo. In this way, no oil could make it to the outside world.
2. We in the aftermarket have been modifying Evolution cylinders like this for years to correct weeping or blown base gaskets. Well, guess what! That is what they did. Right on, no more leaks! Good thing I kept my big yap shut. These people were on top of their game!
3. The bottom barrel O-ring (H-D 11256) sits snugly in a groove cut into the inner engine case right where it meets the cylinder.
4. There is a second O-ring (H-D 11273) around the dowel locator-oil passage (16595-99, 16595-99A), one in each cylinder.
5. A third O-ring (H-D 11273) sits around a second dowel locator pin on the opposite side of the spigot hole on early year Twin Cams.
6. Other than the three O-rings, there is metal-to-metal contact between the former barrel base gasket surface and the crankcase gasket area! The machining and metallurgy is superior to what has gone before. The cylinder base gasket surfaces with the two engine case halves are machined together to provide a uniform fit.
7. Apparently machined separately to each other, some year Evo casing halves were made in different operations and/or locations so that sometimes the gasketing area did not match, the result being leakage.

Twin Cam Hypereutectic Pistons

1. The hypereutectic aluminum pistons accommodate the standard 3-ring set-up.
2. The same piston is used front and rear with a directional arrow on the crown to instruct even the most inattentive mechanic to point the piston to the front.
3. The wrist pin hole is offset slightly to counter thrust forces while traveling the cylinder length.
4. The wrist pin is big, and I mean big with a correspondingly big wrist pin bushing in an equivalent connecting rod meaty enough for the biggest engine. An Evolution wrist pin is .792" thick while the Fathead's is a whopping .927" in diameter.
5. As I said, this engine is a platform for bigger things to come. Oh, yeah, and besides the piston oil-cooling jets that we're going to talk about later, we'll also discuss the black Teflon coating on the pistons from the oil ring down, and the copper coated bottom-end-bearing cages. These features ensure correct break-in amongst many other small incremental improvements in this engine. This engine will last much longer than any Harley rider has ever experienced.

Hypo, Hyper, and Eutectic Pistons

Hypereutectic refers to a piston-manufacturing technique, different from the traditional hypoeutectic and eutectic cast or forged process, due to its unique aluminum alloy. Harley-Davidson has always used cast pistons; forged ones being the accepted domain of the high-performance builders.

Pouring molten alloy into a mold forms the cast piston.

1. Pounding a block of metal into a slug using extreme pressure shapes forged pistons, which are then finished to specification via robotic CNC milling.

2. Forged pistons are more expensive to make because of the tooling involved. They are denser in composition, stronger and more durable than cast pistons. There is no metal porosity with forging, ductility improves, and they run cooler than a cast piston. However, they are noisier than cast until at operating temperatures because of greater expansion rates requiring a looser fit in the cylinder.
3. Cast pistons are quieter, do not expand as much, and can be fit to the cylinder wall with closer tolerances.
4. Hypereutectic refers to the amount of silicon above 12% used in the cast piston alloy.
5. Eutectic is the 12% silicone saturation point in aluminum.
6. A hypoeutectic piston is one with silicone content below 12% and has been widely used in the past in Harley's, generally with around 9% content.

Eutectic pistons replaced the early Shovelhead, Panhead, and Knucklehead hypoeutectic version in the late Shovelhead years around 1981 as H-D was initiating the Evolution upgrades. The eutectic pistons are stronger and still inexpensive to make. Hypereutectic is a cast piston with greater than 12% silicon content. If the piston has 17% silicon content, 12% dissolves uniformly throughout the alloy while the remaining 5% crystallizes as primary insulating silicon crystals, which resist cracking in the piston crown area where temperatures are most severe. The primary crystallization prevents heat transfer to the more vulnerable piston skirt thrust areas, allowing them to run cooler.

1. Hypereutectic pistons also have the smallest expansion rates of any other of the piston types discussed here allowing, for the very close fitment to cylinder wall as seen with Twin Cam use.
2. Twin Cam Hypereutectic pistons are the strongest of the three types.
3. They are most resistant to piston-to-wall scuffing and are least likely to suffer a seizure situation. This is another reason for Twin Cam reliability in the top-end.

Twin Cam Engine Cases

Engine cases (TC88A first use; silver 24596-99; black 24597-99) include sprocket shaft (H-D 9028, 24604-00D), pinion (24623-99, 24604-00D) and cam (H-D 9198) bearings as well as two piston cooling jets (22307-99), one for each cylinder and piston. Engine cases are not for sale without another legitimate damaged set turned in for exchange. The replacement engine cases will have the same serial number also known as a VIN (vehicle identification number) as exchange set.

1. The engine casings are high-pressure die cast aluminum that split down the middle like always; these beauties promote rigidity, strength, and durability as the framework for what is inside and on top.
2. The 360 specially formulated proprietary alloys are designed especially for these cases and the quality is evident as soon as viewing them.
3. Cast into the inner case is the word *Mercury,* known for its high tech quality castings. No more leaks. No more cracks.
4. We fit a set together for a photo, and we couldn't get them apart. Skip, the engineer was apologizing. Why apologize? They fit like a glove.

5. A major problem when manufacturing engine casings is how many times they require clamping them for a machining process. Every time this occurs the alloy deforms, which can cause machining distortions as the alloy bounces back to its former shape before clamping. Less clamping means a superior product. Evolution cases require clamping thirty-two times before fully machined. The Fathead cases need only five!
6. Kenny Sutton, the VP in charge of making these engines, is justifiably proud of them, as should be the people who designed them. Why, he even offered me a job if I could figure out how to reduce this clamping-number further. I think I will stand on other merits. With present technology, Kenny and H-D are at the edge already.
7. Kenny is powder coating the component engine support pieces wrinkle black after casting or molding but *before machining.* Think about it. This powder coating is tough and durable. There is that word again…durable!
8. The scavenging plate or collection center for the oil re-situates from the top rear portion of the Evolution cases near the oil pump to the bottom of the Fathead casings. Why not let gravity do the work. Furthermore, oil is prevented from sloshing around on the flywheels causing drag.
9. The oil pressure-sending switch (26561-99) is now on the front of the right pinion-side case, near the new location for the oil filter (chrome 63798-99).
10. The rear of the casings looks much different. The engine cases hug and bolt to the transmission case, providing enough rigidity that the engine could run without the traditional support provided by primary casings.
11. What may not be noticeable right away is that the oil pump disappears because of this hugging. Yep, the pump is nowhere in sight until looking inside the engine on the pinion shaft.
12. The stator hole is near the same spot as on the Evo, but it is round to provide easier and more effective sealing.
13. Finally, there is a sensor hole on the front left casing near the stator hole. The magnetic sensor picks up signals from the notched sprocket side flywheel to determine flywheel speed and piston timing location.

The TC88 Flywheel (Crank) Assembly

1. The first thing I noticed on the table with the disassembled engine parts display was the humungous pinion shaft bearing (24623-99) about 3 ½" in diameter It is about double the size of that of the relatively skinny needle roller bearing in the Evo.
2. It sat on a beefy pinion shaft forged as part of the right-side flywheel. The Fathead pinion shaft is .400" thicker than its Evo counterpart at the pinion bearing location. This pinion shaft was not going to break.
3. The pinion shaft supports and rotates the geroters (feed pressure set 26464-99; return scavenge set 26465-99) in the dry-sump geroter oil pump (26035-99) inside the timing chest compartment.
4. The flywheel integral pinion shaft end extends through the cam support plate (24607-99) to also support and rotate the small 17-tooth silent chain gear (25609-99) that drives the 23-tooth rear sprocket cam drive gear (25563-99) via the primary silent drive chain (25610-99).
5. Total flywheel weight is 36lbs. I weighed a set and compared this weight from the Evo's 32lbs and S&S's 25lbs, although the Twin Cam flywheels looked lighter.

6. A lot of the extra Twin Cam flywheel (23957-99) weight is from the massive components like the pinion shaft, crank pin assembly, and connecting rods, but the rotational mass is close to the Evo's. There are no H-D part numbers for individual crank flywheel assembly parts since Harley does not sell them.
7. The quality appears to be on a level with S&S flywheels, except everything is obviously stronger, which is a mouthful to spit out as those of you familiar with S&S probably regard their components as being the best in the industry.
8. S&S stroker connecting rods are big, but these are bigger. They also make the Evolution and predecessor connecting rods look puny.
9. The sprocket shaft is also integral with its flywheel, and it has the same dimensions as its Evo counterpart. The sprocket shaft tapered Timken opposed bearings arrangement has not changed, as they were always very reliable since first use in 1956. To my dismay H-D did eliminate their use circa-2002 in favor of a roller bearing.
10. The left-side flywheel has slots machined into its outer rim in order for a magnetic sensor to read the crank speed and position for the carbureted and fuel injection, spark ten-by-sixteen cell, matrix map.
11. The map, table, or matrix, take your pick, is a series of cells with gradated spark settings determined by throttle position and engine load allowing for more precise ignition timing.
12. The table also links to and controls fuel injector on-time for gas delivery on EFI models. Previous electronic ignition modules are more like an on-off switch.
13. In addition, no, I did not make a mistake; H-D uses these spark maps on the carbureted models also as part of an engine management system.

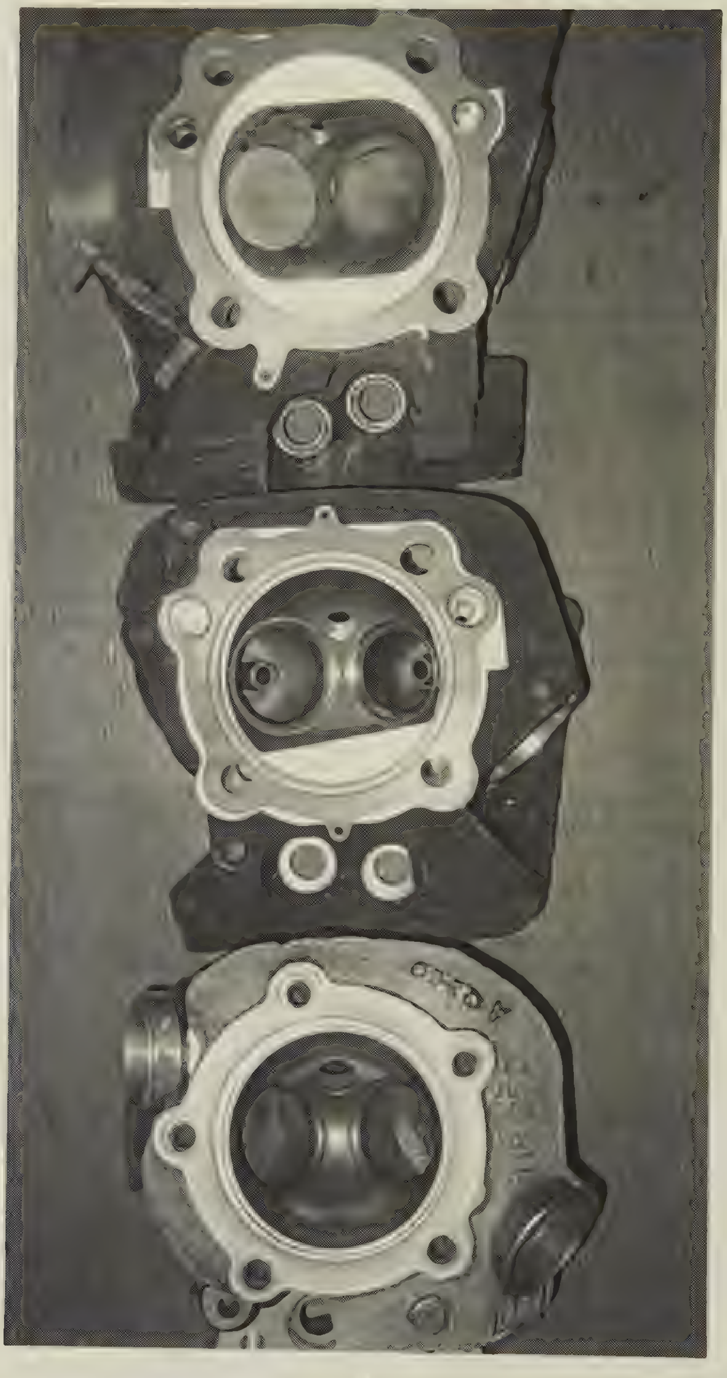
The Crank Pin

1. The large, straight crank pin, .007" interference press-fits into each flywheel half. For reference, a fine human hair may measure at around .003".
2. The three-hole oiling crank pin that replaces the Evolution and predecessor engine single-hole crank pins is a welcome feature that the aftermarket has been using forever.
3. The pin is so muscular that it is just shy of ½" thicker (.420"), than the diameter of that now-skinny old single-oiling-hole crank pin used in the Evo.

I will leave 1998 for a few paragraphs and scoot into the year 2007.

The 1 ⅝" diameter crank pin has a feature that few know about. It is a total departure from anything ever used on a Harley in its entire history. I did not figure it out until I started writing this book nine years later when I took a set of Twin Cam flywheels apart just to poke around. I did this because another difference between Twin Cam flywheels and predecessor ones like the Evo is that shops have not started to rebuild Twin Cam cranks. There has been no need to because the majority of them are so reliable.

Many of those few problematic flywheel assemblies were returned to the Factory for inspection and analysis of any possible impending problems. Even mechanics that work on Twin Cam engines all the time mostly have not had an opportunity to look inside the crank assembly. By the time we were nine years into the Evo, we had probably rebuilt a hundred bottom ends of this vintage at Heavy Duty Cycles.



Knucklehead, Evolution, and Twin Cam Combustion Chamber Head Comparison

Top is a 1999 to 2006 TC88 head showing the head gasket and combustion chamber with a wraparound *squish band.* Visually a TC96 (2007-to-present) combustion chamber looks identical. Center is a 1984 to 2000 Evolution head with a D-shape squish band. The bottom head is an example of the hemispherical combustion chamber used on all Big Twins from the 1936-1947 Knucklehead (shown), 1948 to 1965 Panhead and the 1966 to circa 1985 Shovelhead without benefit of a squish band. I purposely placed the appropriate head gasket on each head so the reader can visualize the Evo and TC88 round flattop piston size relative to the reduced size combustion chambers. The Knuckle's head gasket mimics the size and shape of the hemi-combustion chamber it seals. The Evo head has a "D" combustion chamber that visually mimics the letter D. The round Evo flattop piston rises in the cylinder, *squishing* the air and gas turbulently into the smaller D-combustion chamber. The rest of the circle minus the D is the squish band that the piston meets, with about .040" tolerance left between them when the piston is at TDC (Top Dead Center). The turbulence this creates on the upward compression stroke mixes the air and gas exceptionally well so that a higher percentage of it will burn. Combustion creates heat and thus expanding pressure to drive the piston down on the power stroke. This is the primary reason the Evo is so much faster than the Knuck/Pan/Shovelheads, which have a hemi-shaped chamber and mating hemi-piston without the benefit of squish. Less fuel burns in the hemi-head because the air and gas mix poorly. The Twin Cam head has a bathtub-shaped combustion chamber with prominent squish bands primarily on two sides with two thin strips of squish band connecting the two main ones. This, of course, is a more efficient design than the Evolution because of more squish and therefore more turbulence resulting in an even higher percentage of burn. For emissions control reasons, the Twin Cam head ports do not flow as much air and gas as the Evo heads. We have a better design but less air-fuel delivery to burn. The bigger diameter intake valves are the same in both Evo and TC88 heads, but the Evo exhaust valves have a slightly wider (.030") diameter head. At Heavy Duty Cycles, we routinely put Evo exhaust valves into early Twin Cam heads to increase port flow. The 18mm spark plug hole on the early Knucklehead reduces to a 14mm spark plug hole on the Evo head and to a 12mm hole on the Twin Cam largely because of combustion chamber size and shape. The Knucklehead (shown) and Panhead intake and exhaust valves are the same size while the more modern Shovelhead uses a much larger intake valve than exhaust. The Knucklehead gasket is fibrous in nature and contains asbestos. Asbestos is carcinogenic and therefore, no longer used in North America. However, it made great sealing gasket material for cast iron cylinders against either cast iron heads (Knucklehead) or alloy heads (Panhead and Shovelhead). Both gaskets shown with the Evo and TC88 heads are later hi-tech MLS gaskets.

Knucklehead, Evolution, and Twin Cam Combustion Chamber Head Comparison

Evos and TC88's used thick fibrous wire mesh gaskets that easily take up vagaries in the gasketing surfaces. MLS, the acronym for multi-layer system, head gaskets require a very smooth surface to function correctly. MLS gaskets comprise of three separate layers of stainless steel or aluminum. Later TC96, TC103, and CVO 110 engines utilize MLS head gasketry. The Harley-Davidson MLS gasket's two outer layers are embossed in .001" thick Viton rubber-coated stainless steel. Never use any sealer whatsoever with these gaskets. The MLS gaskets are corrosion resistant, reduce bore distortion, and withstand extreme cylinder pressures. They are superior on a smooth surface but easily blow on a distorted one. The Evo and TC88 heads appear to have 6 holes when there are only 4-headbolts. The extra 2-holes, the equidistant wider ones, are for cylinder-to-head dowel locating pins. One locator dowel does double duty as a channeling feature for oil return from the top end to the bottom end on the Evo and the top end to the timing chest compartment on the Twin Cam. The Knucklehead as does the Panhead and Shovelhead uses 5-headbolts without benefit of locator dowels. Knuckleheads and some Panheads use an external oil-feed-line from the top end to the bottom end. However, Knuckleheads, Panheads, and all Shovelheads utilize an internal drain line from each head through the cylinders to the bottom end.

Rebuilding a Twin Cam Flywheel Assembly

However, even if wanting to rebuild a Twin Cam crank, no parts are available. H-D has no listing for separate crank parts. Harley only sells the flywheels as a complete unit. When one starts to think it, through, are they even rebuildable? Once apart and pressed together again, the interference fit of the flywheels will not be the prescribed .007" press. There will not be a tight enough fitment as some mating metal is scraped away both in the removal and the reassembly process.

There are three main ways of dealing with this lack of rebuild-specified interference fit other than resorting to a completely new crank.

1. One is the usage of adhesives; space age adhesives. Loctite and other chemical adhesives will more than make up for a few thousandths of an inch. If visualizing the words *chemical weld*, the concept is easier to grasp.
2. The mechanic must use heat and cold to re-press the flywheels together on the crank pin ends. Even a .005" press interference fit will peel metal away during the press process if mating component parts are at room temperature. Contracting the crank pin in diameter sizing by cold, perhaps even nitrogen cold, while heating the pin apertures in the flywheel halves is necessary. This will get the initial assembly interference fitment below .005" to prevent metal peeling and retain the integrity of the parts after they return to equally even and normal temperatures. Application of the chemical adhesive is before reassembly. The adhesive sets as temperatures normalize.

3. The other way of maintaining correct interference fit would be with oversize crank pin ends but not the center part, where bearing and connecting rod big end fitment is concerned. The captured caged bearings will fit over a crank pin end that is a few thousandths of an inch bigger as will the connecting rod big ends. However, if placing the caged bearings inside the con rod big end journals beforehand, they will not fit over the enlarged crank pin end. Therefore, the bearings should be installed first and then the con rod journals, which is not a big deal.

Flywheel Truing Specifications

Truing the Twin Cam flywheels requires fast thinking, fast hands, and lots of know-how. Harley specifications call for runout at the Twin Cam flywheel rims for between .000" to .010" at the rims. [4] I can go for zero runout, which is a mechanic's dream but *a full ten-thousandths of an inch (.010") is way out of line* in my experienced, opinion.

Traditionally, most times H-D calls for a maximum .003" runout at the rims.

Flywheel shafts conventionally must true to within .001". In 1999, the specification relaxes to .000" to .002". [5] I initially thought I was reading a misprint in the workshop manual for the Factory's specification limits, so I checked three different years. I did not misread the manual at all. The Factory says to check runout at the flywheel shaft adjacent to the flywheel itself. It is easier to do here because the bearing surfaces are concentric. However, two-thousandths of an inch at this location can extrapolate to much more at the end of the shaft.

Unfortunately, the oil pump and pinion bushing in the cam support plate are near or at the end of the shaft. These parts are soft and cannot withstand an errant shaft not trued as perfectly as possible.

In 2007 specifications increase once again from .000" to .004" that retrofit back to 1999 increasing the previous specification. [6] We true our flywheels at Heavy Duty Cycles, no matter the year, to a maximum of only three-thousandths of an inch (.003"), at the rims and .001" at the shafts. We aim for .000" at both the rims and the shafts and many times approach that perfect figure particularly *on the end of the shafts in the tenths-of-one-thousandths of an inch.*

We never rebuild a set of flywheels with so much runout as allowed in later specifications. Vibration is the immediate result, with premature wear of associated parts coming before their time. The vibration is not as noticeable with rubbermount or counterbalancer dampening. In these cases, one component is creating the problem while the other is masking it.

In our experience both S&S Cycle, Inc. (www.sscycle.com) and JIMS Machining (www.jimsusa.com) flywheels rarely have more than .001" at either location.

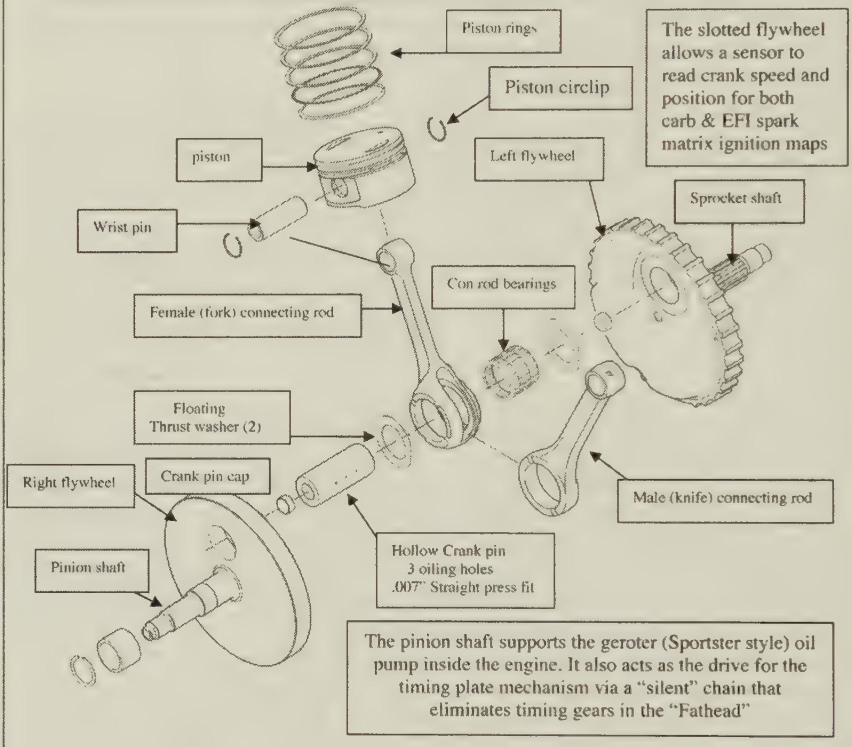
1. Flywheel rims may be closer to each other on one side than the other.
2. Of course, the opposite is true as well as flywheels can splay outwards away from each other.
3. They may also be out of true and cocked forward and back relative to each other.

Checking runout is necessary at both at flywheel rims and at or as close as possible to the ends of the sprocket and pinion shafts although the Factory advises doing this on the bearing surfaces of the shafts near the flywheels.

Flywheel Assembly
(crankshaft)

The sprocket (left) side flywheel and pinion (right) side are one piece. The weight has been redistributed to produce less inertia, which will mean faster acceleration off the line.

Pistons have a Teflon coating to assist in break-in. Connecting rods are massive with corresponding increased size wrist pins and bearings. Pinion shaft, pinion bearing and crank pin diameters make Evo ones look puny by comparison.


Piston rings
Piston circlip
piston
Left flywheel
Sprocket shaft
Wrist pin
Con rod bearings
Female (fork) connecting rod
Floating
Thrust washer (2)
Right flywheel
Crank pin cap
Male (knife) connecting rod
Pinion shaft
Hollow Crank pin
3 oiling holes
.007" Straight press fit

The slotted flywheel allows a sensor to read crank speed and position for both carb & EFI spark matrix ignition maps

The pinion shaft supports the geroter (Sportster style) oil pump inside the engine. It also acts as the drive for the timing plate mechanism via a "silent" chain that eliminates timing gears in the "Fathead"

1999 to 2006 Twin Cam Flywheel Diagram

The 2006 TC88 Dyna and 2007-to-present TC96 Flywheel diagram would look the same as the 1999 to 2006 (except 2006 Dyna) TC88 diagram with 2 major visual differences. The first is the connecting rod *small ends,* which house the piston wrist pins are not square or box-like as with the TC88 except 2006 Dyna. The later con rod small ends taper from a full width at the bottom to a pointed shape at the top. This is to lessen flywheel-reciprocating weight, which I will describe in detail in the main text. The second major visual change is that the wide and fewer sprocket shaft splines evident in the diagram increase to 24-narrow splines on the later flywheel assembly. A change not readily and visually noticeable except to an astute mechanic is that the stroke increases on the later flywheels to increase displacement to 96c.i from 88c.i. The increase of ⅜" (.375") in stroke moves the crank pin half that distance ($^{3}/_{16}$" or.1875") closer to the rim of the flywheel. This $^{3}/_{16}$" radius doubles to an increase of ⅜" diameter stroke when we take the extra distance traveled *up and down* into account.

Curiosity didn't Kill this Cat: the Hollow Crank Pin

Modern technicians that replace component parts assemblies after reading electrical gauges and consulting diagnostic charts, many times, are not well versed in rebuild techniques. In 2007, my curiosity and abhorrence of passing on faulty information got the better of me. Therefore, I had to take a set of Twin Cam flywheels apart to see if I had missed anything. My instincts were correct in that I had.

1. The Twin Cam crank pin is not solid steel but is in reality a hollow tube. Mind you, it is a very strong and supportive hollow tube. The hollow center has a diameter of $^{15}/_{16}$" while the solid part is $^{11}/_{32}$" thick, ($^{11}/_{32}$" + $^{15}/_{16}$" + $^{11}/_{32}$") for a total diameter of 1 ⅝". This new-type crank pin is still very much stronger than what went before.
2. Steel caps plug each end of the crank pin. They press into the hollow ends, thereby creating a sealed internal reservoir.
3. Disassembling Twin Cam flywheels is no easy chore. The .007 interference press fit of the crank pin ends into their respective flywheels is a super-tight tolerance that does not want to give way. Dislodging every other H-D predecessor flywheel from its crank pin is child's play compared to the way Twin Cam flywheels are *glued* together by interference pressure.
4. There is no aligning half-moon Woodruff key between the Twin Cam crank pin and flywheel hole, normally found between predecessor engine crank pin and the right side flywheel half. The antecedent separate Woodruff key normally fits into a half-moon indent in the crank pin's tapered pinion side end. When fitted into the right flywheel, the flat sides of the key mate with a flat indent in the flywheel half. This ensures that the oil feed holes align with each other.

5. Similarly, the separate pinion shaft also keyed to its right side flywheel to ensure oil-hole alignment. In later Evolution engine years, both shaft and flywheel became integral so the pinion shaft no longer needs keying to the right flywheel. Wisely, this innovation carries over into the Twin Cam. The flywheel and shaft casting is machined so that the pinion shaft and sprocket shaft are precisely at 90-degrees to their respective flywheel halves for crank trueness. This results in increasing parts longevity and the lessening of vibrational forces.
6. The Twin Cam flywheel assembly is different for a seemingly similar component from anything that has gone before with Harley cranks. There are three oiling holes inside the crank pin, one each to lubricate each set of the three bearing sets and their three respective connecting rod races; two female sets with a male set in the center.
7. To review:
   - Twin Cam oil feeds via the feed side of the internal oil pump through the pinion shaft bushing in the cam support plate and into the pinion shaft oiling passage itself.
   - The pressurized oil travels horizontally through the pinion shaft passage and into the right flywheel half.
   - It then flows up, down or sideways depending on current rotational crank pin location through an internal channel for delivery into the hollow part of the crank pin. A mating feedhole in the crank pin intersects with the oil passage in the right pinion flywheel.
   - The crank pin presses into each flywheel and attaches them together as one unit.
8. The shafts are located in the center of each flywheel while the always-offset crank pin is towards the flywheel rims to create the *stroke*. This offset crank pin determines how far up the cylinders the rotating flywheels component connecting rods will thrust the pistons and then pull them back down. If the crank pin places in the center of the flywheels in alignment with the sprocket and pinion shafts, the flywheel assembly will still easily rotate in its support-end bearings. The connecting rods will now remain stationary while the crank pin and bearings will rotate inside the big end connecting rod parent material races. The attached pistons will remain stationary and not push up and pull down their respective cylinder bores.
9. When the crank pin reservoir is full, pressure from oil still being delivered into the crank pin will force oil out of the three oiling holes to lubricate each set of three bearing cages with 18-roller needle bearings each. The purpose of this largely unknown reservoir has an ingenious simplicity, which is cooling.

These rebuild techniques brings all sorts of technical problems. First, it requires very skilled mechanics. Those from yesteryear like the Panhead era when parts fitment was an art because of inexact manufacturing specifications would be suited to this work. Crank pins and flywheels came differently sized, the result of imprecise manufacturing back then as different operator machinists made most everything on lathes. Imprecise machining combined with the vagaries of inexact heat-treating relative to final sizing technology of the day made for interesting and sometimes challenging assembly techniques.

The disassembled Twin Cam flywheel's crank pin holes may not be perfectly round. In these cases, the holes will need to be re-bored to a round fitment size with precise tooling available in any machine shop or sophisticated mechanical service department. We cannot go too big or the flywheel half will need replacement. For the technically proficient, this procedure would be simple. Heat and cold fitment is again necessary to prevent metal peeling during the pressing process.

However, my crew and I began re-truing the Twin Cam cranks in 2008. For the rebuilding, re-truing and balancing technique, please see Volume II: *Performancing the Twin Cam*, Chapter V: *Twin Cam Vibration* for a comprehensive discussion. In a nutshell, I borrowed and modified a procedure from the snowmobile industry. After re-truing H-D Twin Cam flywheels, I spot-weld the crank pin ends to the flywheel faces. However, I will briefly discuss re-truing as it increasingly applies to the Twin Cam. *Initial* flywheel assemblies were very true in my experience but as the years progress, specifications become looser.

Connecting Rods

The connecting rods *look* the same, just bigger with more muscle everywhere but they are actually very different.

1. Every other set of H-D connecting rods have separate rod races pressed into the three big ends for the roller bearings to roll in.
2. However, Twin Cam big-end races are made from parent material that is hardened to withstand the rigors of the 54-bearings, 18-per cage.
3. If viewing a set of Twin Cam connecting rod big ends, one might think they were worn badly and in need of replacement because of the metal's purplish hue around the big ends that also extends a little up onto the rod shafts. If this occurred on Evolution or predecessor engine connecting rods, it would indicate excessive heat distortion and replacement would be very necessary.
4. *Parent material bearing* is a tricky phrase as it simply means that the material of the connecting rod itself is hardened to act as a bearing surface. The round holes are sized within tenths-of-thousandths of an inch (.0001” to .0009”), for proper fitment. This is a very small measurement and should not be confused with one-thousandths of an inch (.001”).
5. In 2011, H-D eliminates the connecting rod small end wrist (piston) pin bushings in favor of parent material.
6. The theme of size continues with the captured 3-sets of 18-needle rollers in copper-coated cages. The copper coating helps with break-in procedures, promotes durability, and offers easy wear-spot identification.
7. The roller needle bearings are bigger than Evo or Shovel ones. There are three more bearings than the Evo and late Shovel bearing sets, which use 51-bottom end rollers. The bearings are the same diameter but longer. The term needle may evoke a wrong image; it is descriptive of the cylindrical shape of the roller. The male bearings are ⅜”-long and half that in diameter while the center male rollers are twice the length at ¾”-long, the diameter being the same at $^3/_{16}$”.
8. *Capture* is an engineering term to describe the type of bearing cage that supports each of the 18-bearings per cage around all sides. This type of bearing cage prevents the bearings from rolling sideways off-square with their path and thereby creating drag as opposed to rolling true and straight as designed. The Twin Cam bearings *pop* in and out of their race and will not fall out via gravity like predecessor bearing rollers. Hence the descriptive term captured.
9. There is still the traditional configuration of the single-fork, big-end front, male connecting rod and the dual-fork big-end, rear, female con rod. The male fork, serviced by the wider, center set of bottom end rollers sits inside the dual female forks that are serviced by two narrower sets of rollers, one set for each fork.
10. I have already mentioned the extra-large wrist pin and bushing diameter size that are huge when compared with predecessor Big Twin or Sportster engines.

Twin Cam Crank Pin

The Twin Cam crank pin is unlike any other in use on a Harley-Davidson. It is 1 ⅝" in diameter, a full .420" thicker than the Evolution crank pin. The ends do not taper like their predecessor. The Factory presses the pin into each flywheel half at a .007" interference press fit. Antecedent pins thread at each end and are held in place via crank nuts. Another difference is the TC88; TC96, TC103, and CVO 110 pin is hollow. End caps (not shown), press into each end to create an oil reservoir to aid in cooling. Oil feeds through the pinion shaft via the oil pump and cam support plate. The oil is directed from the center pinion shaft into the right-side flywheel and further out to the offset crank pin. The hole shown is the intersect feed into the crank pin from the flywheel oil passage. When the reservoir is full, oil is forced out via oil pump pressure through three oiling holes (not visible), to lubricate the three sets of bearings. The visible wear is due to the three sets of eighteen rollers that separate the pin from the connecting rods.

11. Bottom-end inertia is only about 70% of the Evo's due to repositioning of the weight in the flywheels. What this means for the rider is less lag time when the throttle is cranked. Off-the-line response is faster than with the Evolution motorcycle.
12. These superlative parts produce rigidity. They are not only bigger and beefier but are manufactured with improved metallurgy that generates less noise and vibration. They provide an excellent base for stock engine longevity as well as for performance upgrades.

Dual Cams and Timing Drive Chains

The emissions driven design necessitated change away from one camshaft with four cam lobes to two camshafts with two lobes each:

1. Yes, two camshafts; two big, beefy cams (25534-99 front carbureted, 25296-99 EFI; 25544-99 rear carbureted, 25297-99 EFI) supported on the inboard (inside) ends in the crankcase by INA caged needle bearings (H-D 9198) and on the outboard (outside) ends in the cam support plate (24607-99) by roller ball bearings (H-D 8990), one for each cam journal end support.
2. In 1998, everyone thought that these outboard ball bearings would prove very strong and an improvement over the Evolution outboard nosecone bushing.
3. There is less inertia imposed on the rotating cam journals when utilizing a bearing over a bushing.
4. Hindsight suggests a much different picture of the inboard journal INA cam bearings and the rear outboard cam journal ball bearing.
5. The front cam ball bearing in the cam support plate has proven to work very well while the rear cam roller bearing does not. Please refer to the cam-support-plate pictures in order to familiarize yourself with these parts since many are alien to anything Harley has used in the past.

6. Actually, H-D uses successive generations of cam support plates (24607-99, 25267-99, and 25355-06) as of 2010. I will be discussing them a great deal because of their importance in the Twin Cam engine.
7. Each cam services its respective head, front and rear. Therefore, both cams have two cam lobes, one for activating it's the exhaust valve and the other for the intake valve
8. The two six-plate *silent* cam chains connecting and driving the two cams is also new.
9. The rational for this chain-driven system is mechanical noise reduction in the engine that requires changing away from the traditional meshing *spur* gears to sprockets and silent plate chain. This design is supposed to produce a consistency in sound as well as the desired reduction in noise. The Evolution and earlier model gears whined when tight and clattered when loose. Since metal expands when hot and contracts when cool, this consequential noise became an insurmountable problem in order to comply with the Environmental Protection Agency. I will list the sequence of events in order of priority leading to the design changes.
10. Noise reduction necessitated the move away from the timing gears to the silent chain connecting sprockets method.
11. If the chain went straight up from the drive gear to a one-cam location, it would necessitate raising the engine-case deck height too high. Engine shape would change too much, and we all know that this would be a big no-no.
12. This led to using two cams with two in-line cam lobes each, side-by-side instead of the traditional central cam utilizing 4-in-line cam lobes.
13. Therefore, the outboard primary drive chain (25610-99) and rear cam is offset from perpendicular about 22 ½ degrees to allow for the desired deck height of the engine cases where the cylinders bolt to the cases.
14. Connecting the two dual cams on a horizontal plane is a silent secondary chain (25607-99) behind (inboard) the cam support plate.
15. The resultant straighter angle pushrods in the valve train gave an added benefit of mechanical efficiencies, such as ridding the Twin Cam of the annoying front-exhaust lifter tick, common on the Evolution Big Twins.
16. The primary silent chain is driven by the rotating crank's pinion shaft 17-tooth cam drive-sprocket (25609-99). This slot-center of the pinion sprocket affixes to the slot-end of the rotating pinion shaft. It powers the rear cam by means of the larger 34-tooth cam drive sprocket (25563-99) via the attaching primary cam chain.
17. The rear cam drive sprocket, keys via an integral key in 1999 to the end of the rear cam outboard journal.
18. Both the cam support plate outboard primary drive chain and the cam support plate inboard shorter secondary drive chain have spring-loaded tensioners (primary 39954-99, secondary 39964-99) for constant and supposedly consistent adjustment.
19. Factory engineers told me they expected these adjusters to outlast the engine. Never has a prediction proved to be so wrong, as we will see in coming chapters.
20. The silent chains have 6-parallel plates per link and are unlike any chain used previously on a Harley-Davidson.

21. The first cams have a .471" lift, at the valve and .290 at the tappet (cam lobe) with the same rocker arm ratio of 1.625:1 as the Evo. The rocker arm ratio multiplies the tappet cam lobe lift to attain actual valve lift (.290 x 1.625 = .47125, which rounds down to .471").
22. Cam design supplements flywheel weight distribution to increase bottom-end torque with needed power below 4000 rpm. This results in a feel-good sensation blasting away from a stoplight. Torque is also necessary to move a Harley-Davidson from a stop to combat the inertial forces created by their excess weight.

Valve Train Tappet Hydraulic Lifters and Pushrods

1. The engine crankcases have holes machined in them to accept the four hydraulic lifters (18538-99) similar to those in the later XL Sportster cases.
2. Twin Cam lifters are based on automotive Chrysler parts.
3. Installation is from the top as opposed to their Big Twin predecessors, which were done from the bottom.
4. Evolution lifters are cast iron while the Fathead ones have a steel body for superior wear characteristics.
5. The lifter pushrods are of two lengths; intakes (17923-99) are equal in length, as are the exhausts (17922-99). The pushrods colored with paint blotches offer easy identification. The color of the intakes is a silver color, while the exhausts are black.
6. My initial impression was that they seem to be made of better quality material; however, in fact, are made from the same steel as the Evo rods.

Oil Filtration

The 1999 to 2006 Twin Cam TC88 as well as the 2007-to-present TC96, CVO 110, and TC 103 reverses traditional Harley-Davidson oil filtration. Oil filters before feeding into the engine, not afterwards as in all previous Harley-Davidson models.

Oil filtration is superior to anything that has gone before capturing a percentage of debris above the size of 10-microns. Micron defines as a millionth-of-a-meter. A meter, which is a metric measurement, is a little bigger than a yard (1 meter = 1.09 yards = 3.28 feet = 39.37 inches). Therefore a micron equals 0.0000394"; 10-microns equal 0.0003937". In 2006, Harley-Davidson lowers oil filtering (63978-99A) to incredible 5-microns or 5-millionsth of a meter; 5-microns equals 0.0001969".

This and other changes have allowed the Factory to extend service life between oil changes from 500 miles initially, to 1000 miles, and then every 5000 miles.

I will examine this topic from 1999-to-present fully in Chapter V: *Twin Cam Lubrication*, section, *Filtering the Oil.*

Inside a 1999 to 2006 Twin Cam Flywheel Assembly

Shown is the 1999-2006 pinion-side flywheel-half, crank pin, con rod bearings surrounded by the male and female connecting rods. The left-side sprocket shaft flywheel is removed. Slots are machined into the sides of the con rod big ends where they encircle the outer bearing cages and crank pin to allow lubricating oil easy access in between the parts. H-D has thankfully adopted this old hi-performancing oiling trick that many mechanics have used forever. The film strength characteristic of oil will always separate moving parts with a layer of oil sometimes only molecules thick. The lower male connecting rod fits between the two-pronged female connecting rod. Shown is the male connecting rod piston-wrist-pin-bushing. This is colloquially known as the connecting rod small end. The 1999-2006 small ends are big and muscular unlike its 2007 small-end counterpart, which narrows and points in order to reduce reciprocating weight. Reciprocating weight refers to flywheel assembly parts that go up and down as opposed to rotating parts that turn. Pictured on the end of my finger is the crank pin end cap that press-fits into the end of the crank pin to create a reservoir for cooling oil. In actuality, the flywheel and component parts are much larger and my finger and crank pin end cap is much smaller. Oil carries away heat as it re-circulates back to the oil tank. This is one reason an oil cooler is a good idea for the Twin Cam engine so that heat may dissipate away into surrounding air. The raised *pork chop* portion of the flywheel half in combination with the indentations to the right repositions the weight of the flywheel to create more torque so that bottom-end inertia is only about 70% of the Evolution flywheels. This means there is less lag time when the throttle cranks for engine off-the-line response. This simple weight redistribution allows the Twin Cam to accelerate faster off the line than an Evolution motorcycle. The paint blotch on the pork chop portion is a Factory identification mark, whose different colors may indicate such things as balance factors. The casting number in the flywheel identifies the part. This part was first manufactured for 1999 Twin Cams as indicated by the last two digits, in this case 99.

The TC88 Oil Pump

All Twin Cam oil pumps are basically the same using the same principles and fundamental component parts. That is not to say that all Twin Cam oil pumps are interchangeable because they are not unless replacing other related component parts in tandem. I will explore this subject from 1999-to-present in great detail in Chapter V: *Twin Cam Lubrication,* sections *The Twin Cam Oil Pump; Twin Cam Engine Oil Feed; Twin Cam Engine Oil Return,* and *The Twin Cam Breather System.*

The Twin Cam oil pump does not use gears like all previous Big Twins. The TC88, TC96, TC103 and the CVO110 all use a dual geroter setup. There is a feed and a return side just like the dual gear driven pumps. The hollow geroters sit one inside the other on both feed and return sides of the oil pump. Nubs on each geroter facing the other squeeze oil to create volume and pressure.

Another big change is that all previous Big Twin pumps externally mount on the right side of the engine casing. The Twin Cam pump mounts internally inside the timing compartment of the right hand engine case. The two inner feed and return geroters mount on and turn with the rotating flywheel pinion shaft. The oil pump body bolts to the inboard (inside) side of the cam support plate.

Furthermore, the 1984 to 2000 Evolution and predecessor timing compartment breather gear eliminates in the Twin Cam engine. The Twin Cam oil pump dual scavenges from both the crankcase, eliminating the need for a breather gear, and the timing compartment. The rear slightly longer oil pump body port that extends downward scavenges returning oil from the bottom end compartment while the front, slightly shorter port scavenges or removes oil from the timing compartment. Both ports feed the removed oil into the return side of the oil pump. Scavenging improves with the 2006 TC88 Dyna and all 2007-to-present TC96, TC103, and CVO 110 engines in order to combat the possibility of oil blowby outside the engine via the breather separation mechanism.

The Factory-recommended fossil oil is H-D 360, 20W50. Any quality 20W50 oil will service the engine well. I prefer the use of synthetic oil once the engine has 1500 miles (2400 kilometers) on it. Fossil oil is not as slippery and lets mating parts wear into each other during the break-in period. My opinion is that further wear is neither required nor desirable once broken in.

Engine oil pressure is 35 psi at 230^0 F at 2000 rpm.

Twin Cam Engine Oil Feed and Return

All TC88, TC96, TC103, and CVO 110 Twin Cam engines from 1999 to present lubricate by a pressurized system that circulates oil from an external oil tank, known as a reservoir in Harleyese, via the internal engine oil pump The pump also drives return oil back to the oil reservoir. Oil has four main functions: cooling, cleaning, lubricating, and sealing. Yes, a seal requires a film of oil in order to function properly in order to contain oil inside the engine, primary, and transmission.

Oil flow inside the engine may accomplish by one or more of seven methodologies; high pressure feed, low pressure feed, splash/oil fling lubrication, air oiling mist, crankcase venting air, low pressure oil return, and finally high pressure oil return.

The engine oil feed and distribution throughout the engine occurs through the cam support plate and crankcase to the oil filter mounted on the front of the engine's right side. The clean filtered high pressure oil routes back into the cam support plate for circulation to various parts of the engine.

Twin Cam engine oil return accomplishes by gravity-drain oil flow from each cylinder head straight downwards through the head and cylinder oil passage. Unlike the Evolution, where oil drains into the bottom end compartment, Twin Cam drain oil enters the left engine case and then travels sideways through the right engine case, front and back, and empties into the cam (timing chest) compartment. This oil now gravity-drains again to the bottom of the timing compartment where it is picked up (scavenged) by the front, slightly shorter-oil pump scavenge lobe (port) for removal via the cam support plate to the oil return geroters. The other longer scavenge port does the same with oil scavenged from the bottom end compartment for oil return.

I will further examine this topic from 1999-to-present in great detail in Chapter V: *Twin Cam Lubrication*, sections, *Twin Cam Engine Oil Feed* and *Twin Cam Engine Oil Return.*

The Twin Cam Breather Vent

The Twin Cam breather air-oil separator arrangement is an improvement over the 1992 to 2000 Evolution system. The breather in each head extracts gaseous oily substances from the air to allow the engine to breathe cleanly. The breather is supposed to prevent oil from exiting outside the engine.

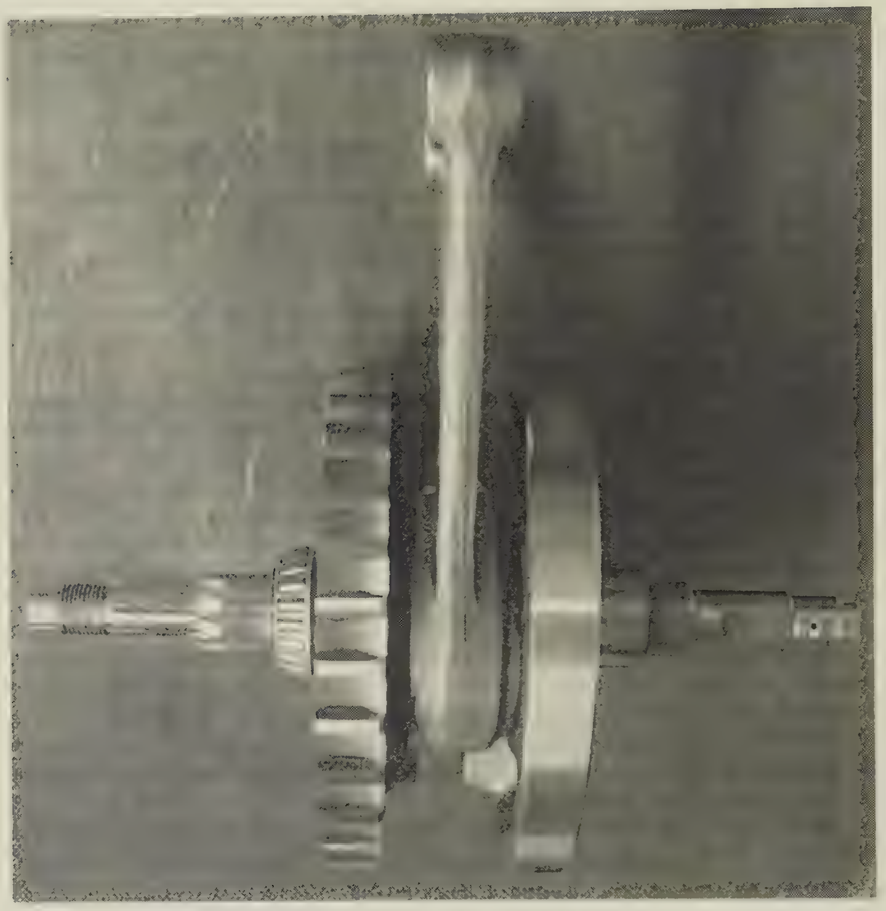
After 1999, apparently this supposed former problem is not going happen anymore. Please see Chapter III: *Harley Oil Leaks: Marking its Spot* in this volume for comprehensive information on the breather system and what it must contend with.

When both pistons move downwards and upwards in their respective bores in tandem, there is much displacement of air within the engine. The space below the sealing piston rings shrinks in area as the pistons descend together. Oil vapor and small molecules of oil pick up and suspend in the rushing tumultuous air. The oilified air forces through the timing compartment and up the hollow pushrod tube covers into the rocker box area above the heads. It then travels through the breather apparatus that locates in each rocker box between the valve train's intake and exhaust rocker arms. The breather apparatus separates the majority of the oil from the air. The oil drains away via gravity for return to the timing compartment. The air follows a convoluted pathway, which further separates any remaining oil before it exits each head into the carburetor/EFI breather box. The expelled air then sucks into the engine's combustion chamber via vacuum created by the descending pistons. Therefore, the descending pistons cause shrinkage of air space below the piston rings thus forcing air up into the heads for oil vapor separation. This mostly-cleansed air now travels out of the heads into the air cleaner where the same descending pistons draw this air into the combustion chambers to burn and remaining oil-vapor.

The new Twin Cam, three-stage breather separation system utilizes physical principles to remove most of the oil out of the air. The gaseous mixture must interact with the walls and turns of the separator pathway. The mixture is unable to deal with this interference and heavier molecules of oil liquefy. Wall temperatures are cooler, also further causing vapor to liquefy and drain away. The oilified air now travels through a flapper, which is a rubber, umbrella-shaped, one-way valve that lets air out of the lower engine but will not allow it back in. This part also exists in the 1992 to 2000 Evolution engine. If overwhelmed, the flapper valve will let the errant oil out along with the air. A new open cell-foam part shaped like a one-inch-long barrel, then scrubs oil from the air rushing through. The foam barrel is very porous and air can easily traverse through the foam. Again, heavier oil molecules will liquefy when presented with challenges like the foam's complex pathways.

All three components, the separator, the flapper valve, and the foam barrel fit together. An assembly bolts onto each head through the lower rocker box in between the rocker arm assemblies. Once the gas separates, it flows out a channel machined in the heads, escapes the engine into the air breather, only to be sucked back in through the venturi, and burned for emissions purposes.

Please see Chapter IV: *Harley Oil Leaks: Marking its Spot*, section, *The Twin Cam 3-Stage Venting System* and Chapter V: *Twin Cam Lubrication*, section, *The Twin Cam Breather System* for a comprehensive discourse on this important subject.



The 1999-2006 Twin Cam Crank; a Roller Bearing Replaces the Sprocket Shaft Tapered Bearings in 2003

Pictured is a set of 1999-circa 2002 TC88 flywheels, (23957-99) also known as the crank. For the discerning mechanic these flywheels, easily distinguish from their 2007 TC96 counterparts, as the crank pin is moved $^3/_{16}$" closer to the rim of the flywheels on the TC96 crank (23729-07). This is a radius measurement so that the diameter change is twice that at ⅜". There are no separate part numbers for any flywheel assembly component parts rendering crank rebuilding impossible at this time (2010). H-D does not sell them preferring replacement of the complete assembly. The stroke on the TC88 is 4.000" while the TC96 is 4.375" (4 ⅜"). It would be easy for a mechanic to figure out which crank is the TC88 and which is the TC96 if they were beside each other because crank pin location could be compared. If only examining one set, it would be very difficult to tell by stroke alone. However, the easy way for anyone to tell, other than looking at casting numbers, is noting the shape of the connecting rod's *small ends* that houses the wrist pin bushings (not visible), one in the end of each connecting rod. The 1999-2006 small ends square off in shape. The bushings they house are the same length around their circumference. The 2007-to-present TC96, TC103, and CVO 110 connecting rod small ends have a very different shape...they are pointed...with the base the same size as their TC88 counterparts. Therefore, the piston bushing's length is wide at the bottom of the circumference and steadily narrows as it reaches the top. H-D reduces the reciprocating weight (defined as parts that go up and down, as opposed to rotating) of the con rods and the pistons to help offset the effects of increasing the stroke, which increases piston speed and therefore, the enemy heat. Less mass, traveling farther up and down the cylinder bores in the same amount of time helps combat the momentum of pistons suddenly stopping and changing direction at the top and bottom of the stroke. The female connecting rod *big end* hides its male counterpart since it fits inside the forks of the female rod. The big ends are between the flywheel halves and house the bottom-end bearings, cages, and crank pin. Another easy way to distinguish TC88 flywheels from their TC96 counterparts is checking out the number of splines on the left-side sprocket shaft. The TC88 splines are wider. TC96 splines are very much narrower and there are more of them. Furthermore, TC96 flywheels have a big roller bearing located on the sprocket shaft whereas the TC88 ones may have a tapered Timken bearing (shown) on 1999 to circa-2002 and the roller bearing circa 2003 to 2006. The bearing(s) support the left side of the crank in the left engine casing. The sprocket shaft extends into the primary chaincase to deliver power back through the powertrain. The power side, sprocket-shaft flywheel has notches around its perimeter. A sensor magnet located in an aperture in the front left engine casing reads the notches and sends pulses back to the electronic control module (ECM), computer, which ascertains the flywheel's connecting rod-piston location in order to time ignition spark.

The 1999-2006 Twin Cam Crank; a Roller Bearing Replaces the Sprocket Shaft Tapered Bearings in 2003

The right-side pinion flywheel's pinion shaft extends through the right side-engine casing and into the timing compartment supported by another roller bearing, the same style as used on later Twin Cam sprocket shafts. The longer slotted portion of the shaft supports and drives the oil pump. Oil pump inner geroters have a mating inside slot for mounting and locking in position on the pinion shaft. The round part of the shaft with the oiling-hole fits into the cam support plate's pinion bushing. The oil pump feeds oil into the cam support plate to the pinion bushing and into the oil feed passage hole for delivery to the bottom end components for lubrication. The slotted end of the pinion shaft accommodates the 17-tooth timing drive sprocket (25609-99) that has a mating slot. This sprocket drives the outboard rear cam's TC88 34-tooth gear sprocket (25716-99, 25716-02) via the outboard primary timing chain (25610-99) and then the two inboard cam sprockets via the secondary timing chain (25607-99). Thus, two timing chains drive the whole valve train.

Twin Cam Engine Covers and Gasketing

All engine covers like the nose cone also known more properly as the timing or gearcase cover (chrome 25369-99 to 25369-01B), the split two-piece rocker wafers (chrome 17572-99 upper, 17573-99A lower), and the guide block covers (chrome 17964-99 front, 17966-99 rear) are just that, covers. No more do covers act as load-bearing supports for other engine parts. This innovation helps dampen noise and reduces possible oil leaks, which is very important to the emissions people.

In the Evo, the nosecone supports the pinion shaft and the cam. The lower rocker wafer supports the rocker arm shafts, and the guide block holds the tappet assemblies.

No more, a cover is a cover period. Twin Cam oil leaks are going to drastically reduce.

1. Inside the internal noise-dampening webbed and finned rockers is a separate support plate (17594-99) for the rocker arms. This plate bolts directly to the head through the lower wafer. It also holds the breather apparatus, which consists of the oil separator that does not have a separate part number, the flapper valve (26858-99), and the scrub sponge (63815-99), which I discuss in the oil sections.
2. Inside the larger nosecone cover is a cam support plate (25355-99 to 25355-06) that also directs the oil through the engine from the internal oil pump geroters, similar to those used in the XL Sportster's oil pump since 1977.
3. The engine case supports the tappets also known as hydraulic lifters (18538-99, 18538-99A, 18538-99B) instead of having removable guide or tappet blocks. Chrome covers fit over the tappets.

4. I have not been a big fan of eliminating things like tappet blocks since they are rebuildable and replaceable. Replacing the right side engine case is necessary with this Twin Cam integral engine tappet block, once worn out. However, it looks to me as if there is enough room to accommodate an oversize tappet once the original tappet hole wears. The engine case tappet hole will need reaming for bore trueness and fitment for a larger diameter tappet. I am sure the aftermarket will come to the rescue by manufacturing oversize tappets. As I look back from 2010, I must report that my initial nervousness appears unfounded since I have never yet had occasion to neither fit an oversize tappet nor replace an engine case because of excessive wear in this area. I am just an old-school mechanic that does not like a rebuilding alternative taken away.

The quality of the aluminum is very much superior to that used in the Evo, which will stave off problems, as will the cleaner oil that this Twin Cam engine utilizes because of superior filtration as the oil enters the engine. I will discuss this in greater detail as I progress.

Twin Cam Gaskets

I cannot help myself. I get excited just thinking about them. Service departments are going to lose a major source of income in replacing defective or weeping gaskets. Take the rocker gaskets (17386-99 top, 16719-99 bottom) for example. Rubber coating with an embossed steel core provides uniform pressure throughout. The embossing is a ridge, if you will; something like the silicone beads now found on high-quality aftermarket gaskets, except it is a coated metal. This metal embossing goes around the bolt-holes, as well as the gasket surface to provide a uniform pressure seal on quality machined surfaces.

I understand that like you, I have been suffering from Harley oilitus for thirty years now. The cure is here. No longer should Harley mark its spot...at least from oil leaks.

Engine Compartmentalization

The engine is further compartmentalized in the TC88, TC96, TC103 and CVO 110 relative to antecedent engines. The two lower compartments, the timing chest, and the crank cavity connect in the Evo. I know this may be a little confusing but read on. The Twin Cam engine divides into three sections for oil-related purposes. They are the:

1. Crank compartment.
2. Timing chest.
3. Heads.

In the Evolution, this separation is not as defined because oil sloshes around wherever the forces of physics take it.

Defeating Noise

Noise emissions are controlled by EPA guidelines. It is an ongoing battle for Harley-Davidson to meet noise reduction mandates because of old technology and the fact that Harley riders love noise. The Twin Cam addresses noise issues in some novel ways:

1. The no-load bearing, ribbed inside engine covers help dampen noise.
2. The elimination of timing gears and the use of silent timing chains are supposed to be the biggest noise reducer.
3. The higher volume intake manifold also makes a big difference in power and noise dampening.

Why is noise dampening such a concern? The traditional throaty Harley exhaust noise that we all love is why. The determining factor is the overall noise level generated by the motorcycle. The representative sample motorcycles are ridden through a decibel noise-reading trap at a certain rpm. Eighty decibels is the 1999 magic maximum number.

There are three sources of noise:

One is the exhaust noise that we like.

1. Two is intake manifold noise, about which we are neutral.
2. The third, which we do not like, is mechanical noise, from the timing chest.
3. The ride-by noise test is a measurement of all three. Lowering the intake manifold noise and mechanical noises will allow the throaty sound of the exhaust to remain. This is very important to the H-D rider, as it is part of the Harley mystique. However, it is a losing battle.

Harley-Davidson begins a subtle ad campaign directed at its loyal following to reduce noise especially by backing off the throttle in sensitive areas like hospitals or schools. I originally thought they were pissing into the wind but looking back from 2010, the promotion was largely successful. In fact, those with drag pipes are now frowned upon when they ruled for decades.

The Transmission Housing: Structural Strength

The transmission box or housing is definitely different as it now hugs and attaches to the engine cases to produce rigidity.

In previous models, the primary system provides structural strength and rigidity in addition to quieting primary chain noise. The primary also keeps dirt out and clean lubricating oil in. As 1990 to 1998 Dyna riders found out, the primaries were not enough to control engine sway. Aftermarket torque arms, which are a structural support, were required to join the engine nose cone more properly known as the timing cover to the transmission.

This new Twin Cam system is so strong that the primaries, while an added benefit, are not necessary for this function anymore, not that you want to throw this additional support away. This rigidity throughout the Fathead combined with a new rubber mounting system for the 1999 Dyna has produced the first Harley hotrod since the FXR.

In March 1998, Harley engineer, Skip Metz's eyes lit up with pride when telling me all this stuff.

The 5-speed transmission gears are the same as before, as is the nine-plate clutch introduced on 1998 models.

Heat Treating

Kenny Sutton, the person in charge of making all this stuff, showed us thousands of transmission gears in the process of heat-treating in the traditional oven-quench format. We also observed cams in the process of heat-treating by modern wave technology: In a mere twenty seconds, a cam becomes red hot and is then quenched to produce a .040" thickness of the desired hardness.

Machining Irregularities Caused by Heat Treating

Nevertheless, what got Kenny excited was new technology that did not even exist ten years ago to make the transmission gears quieter. Elimination of any mechanical gear noise is very important. The gears used to be straight cut, and they clattered away as they interacted. Then the Factory evolved full-contact ratio gears. The machined gears roll into each other utilizing the whole contact area available. This disperses pressure and produces less noise. However, the gears have to be heat-treated, which causes some distortion to the machined surfaces, causing high points that result in noise. The new technology allows the machining of the gears again without damage after the heat-treating process. The result, said a beaming Kenny, is a quieter gear.

Primary Gear Ratios

In 1998, all TC88 Dyna and FLHT models used a twenty-five-tooth motor sprocket and a thirty-six-tooth clutch sprocket (25/36) giving a 1.44 ratio. This means there are 1.44 engine revolutions for one rotation of the clutch hub and therefore the transmission mainshaft.

The TC88 carbureted models still use this ratio until 2006 while the fuel-injected models have changed to a twenty-four and thirty-seven-tooth (24/37) configuration primarily to ease up on the starter motor also up until 2006. This produces a primary gear ratio of 1.54:1. This means there are 1.54 engine revolutions for one rotation of the clutch hub and therefore the transmission mainshaft. After 2006, the sprockets increase in size to 34-teeth on the engine and 46-teeth on the clutch sprocket (34/46). I delve into all year gear ratios (primary, secondary, final and internal transmission) and what they mean extensively in Chapter IX: *The Controversial Harley 6-speed Transmission.* The information is relevant to any year Harley-Davidson 4, 5, or 6-speed transmission and powertrain.

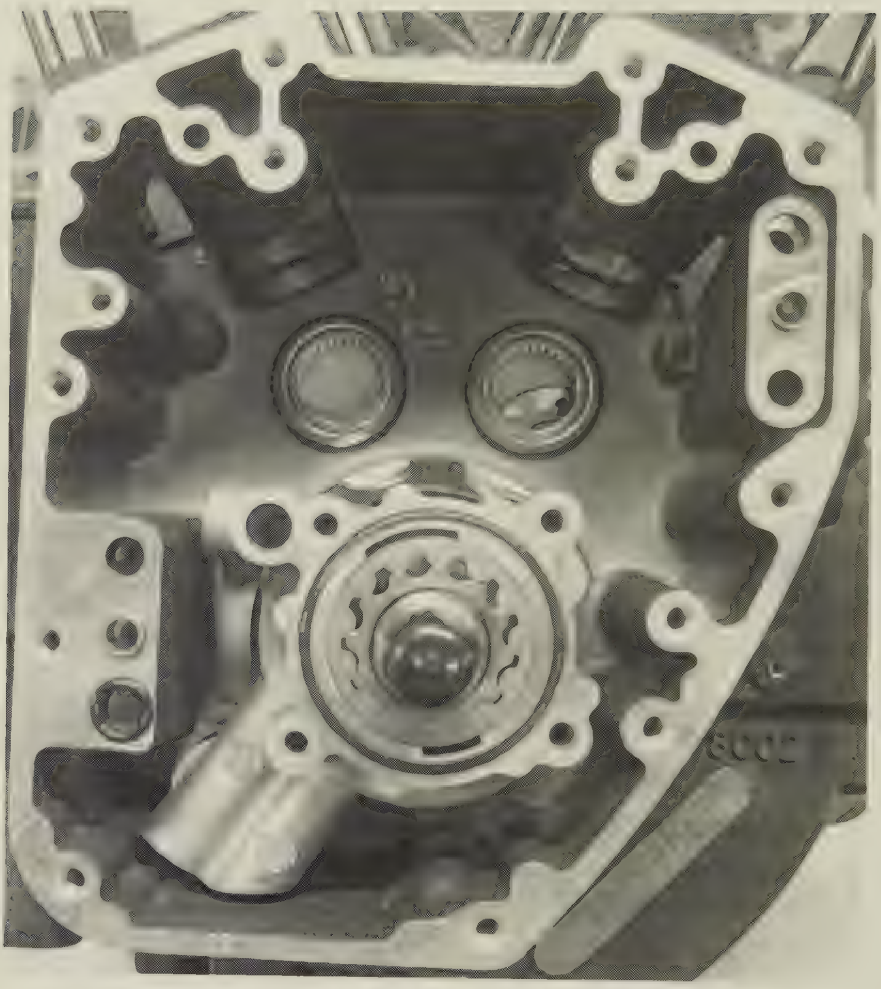
The Primary Derby Cover

The primary derby now has a quad seal, which is a definite upgrade as are the five-derby hold-down screws compared with the round rubber seal and three screws on the Evo.

Success in the End evolves from Failures in the Beginning

As Skip Metz told Buzz, Chris, and I in March 1998, "Success in the end makes failures in the beginning worthwhile." [2] Moreover, H-D has succeeded by defeating early failures over a 4 ½ year development period, which began in 1994 when first conceptualized.

I wrote this article in March 1998 during my stay with Harley-Davidson in Milwaukee. My last comment is that this is the most exceptional motor ever developed by Harley-Davidson. Congratulations to Harley-Davidson on a superb effort.



The Internal 1999-2006 Twin Cam Oil Pump

Pictured is the inside of a 1999 to 2006 Twin Cam engine-timing compartment. The rotating pinion shaft supports and drives the 1999 to 2006 Twin Cam oil pump (26035-99, 26035-99A, 26035-99B). Each successive part number indicates a refinement of the original oil pump. The pump is located inside the engine in the timing compartment on the right side of the engine below the air breather. Previous Big Twin oil pumps were gear-driven and located outside but attached to the engine. The TC88, oil pump, positions inside (behind), and bolts to the inboard cam support plate (25267-99B). The similar but different TC96, TC103, and CVO 110 oil pump (26037-06) positions the same behind an updated cam support plate (25355-06). Pictured is the set of mating feed side geroters (26464-99). The return-side geroter set (26465-99) is behind these and housed on the opposite rear side of the pump. The 1999-2006 TC88 (except 2006 Dyna), geroter nubs are twelve/thirteen; the outer geroter has thirteen inward-facing nubs that interact with the twelve outward facing nubs of the inside geroter. Oil flows in the feed side between the geroters and becomes trapped. As the pump geroters rotate on the pinion shaft, the oil squeezes into a progressively smaller and tighter space, creating pressure as it forcefully exits the pump. The 2006 Dyna and 2007-to-present TC96, TC103 and CVO 110 pump pumps 10% more feed oil plus the pump scavenges 23% more return oil. The new 2007 pump has a ten/eleven nub arrangement, which gives it increased capacity. The dual-scavenge ports or lobes colloquially known as *dual kidney* ports face downwards to the bottom of the timing chest in order to suck up oil into the return geroters on the return side of the pump to send the oil to the oil tank (reservoir). The rear slightly longer port scavenges returning oil from the bottom end compartment while the front shorter port scavenges or removes oil from the timing compartment. Both ports feed the removed oil into the return side of the oil pump. Above the oil pump, the two .875" inner diameter rear-cam journal bearings (H-D 9198) sit in the engine casing. Beginning with the 2006 Dyna and continued into all 2007-to-present Twin Cams, the rear cam journal bearings (H-D 9215) diameter increases to 1.000". The front cam-journal bearings (not shown) are located in the cam support plate. The engine case serial number is stamped into the casing towards the front of the timing compartment below a casting number, 8002. A raised casting number always identifies a part. A stamped-in serial number always identifies an engine or vehicle identification number (VIN). There may be up to hundreds of thousands of identical casting numbers on identical parts, but there will only be one serial number of the same sequence.

Single Fire Ignition Spark Map

The ignition is now single fire with no wasted spark on the exhaust stroke. This has been a high-performance upgrade for years now by the aftermarket and finally in 1999 the single-fire ignition will become stock on all Fatheads for both carbureted and fuel-injected models. Previous carbureted Big Twins have had the more economical dual fire ignition systems where the spark plug fires on both the compression stroke, which is necessary and also on the exhaust stroke, which is unnecessary and wasteful.

Ignition Timing

It is crucial that spark occurs sometime during the latter stages of the compression stroke before the all-important power stroke begins because:

1. It takes time for the oxygen assisted gas molecules to begin burning. This process is known as combustion lag.
2. Furthermore, it takes more time for the actual burning flame front to travel across the combustion chamber.
3. Spark timing must occur so that burning creates maximum heat, which expands causing the pressure required to drive the piston down on the power stroke at the most opportune moment in time.
4. Therefore, spark must occur before the power stroke somewhere during the previous compression stroke. The *somewhere* largely determines by piston speed:
    a) A slower moving piston will allow more time for optimal combustion. Therefore, timing will *retard* or occur closer to piston TDC (top dead center) on the compression stroke because the slower moving piston will allow optimal combustion time.
    b) A faster moving piston will require the same amount of time for optimal combustion to occur. Therefore timing will *advance* or occur further away from piston TDC known as BTDC (before top dead center) to allow combustion adequate time.
    c) Emissions controls may alter these optimal advance-retard ignition settings as environmental concerns, many times take precedence over optimal power considerations.
    d) However, in theory there should be a marriage between optimal power and emissions controls since both depend on complete combustion to produce expanding heat (power) and total burning of pollutants (emissions). In practice, this is not always so, making compromises between the two often necessary.

Spark Map

A Harley-Davidson single fire electronic ignition control module (ECM, ECU or ICM, take your pick) with advance and retard timing spark map cells instructs the spark plug when to go off according to load and rpm. The new system has the aforementioned 10 x 16-cell matrix spark map/table that also links to a fuel pulse width table on EFI models as part of a total engine management system.

Each engine load (cold idle, acceleration) or no-load (hot idle, cruising) riding situation combines with an rpm level to form a cell in the spark map that dictates at what point in degrees of crankshaft rotation before top dead center on the compression stroke the spark plug will begin ignition. Ignition retard and advance for the TC88 is 0° TDC for the retard starting position and up to 50° before top dead center (BTDC) for full load high rpm acceleration. As

I said earlier, sometimes compromises must be made between optimal power and emissions controls. Initiating spark at TDC will not produce maximum power because the piston is well on its way down on its power stroke as maximum combustion begins to occur but a TDC retard spark setting will contain emissions.

The spark map settings are nothing more than a *memorized* response table from a dyno laboratory. EFI and the carburetor integrated ignition spark maps are so simple because they do all the work. Setting up and laboriously simulating actual riding conditions on a dynamometer in a scientific lab to develop the memorized spark ignition tables and linking EFI fuel delivery tables for the various load, no-load and rpm settings is not so simple.

CV Kehein Carbureted Ignition

There are four main sensors that feed information to the ECM computer that contains the spark map matrix on timing when the spark plug should ignite on the carbureted models. Using this system with a carburetor is a first for Harley. The sensors vary whether for carburetion or fuel injection. The carburetor sensors with their short form acronyms are:

1. CKP-Crank or flywheel speed and position (32497-99).
2. CMP-Camshaft speed and position (32496-99).
3. MAP-Manifold Air Pressure (32316-99).
4. BAS-Bank Angle (32495-98).

Five other components are required for the carbureted Twin Cam ignition system:

1. Battery.
2. Ignition coil (single fire).
3. Electronic Control Module (ECM).
4. RFI (radio frequency interference) protected spark plug wires.
5. RFI spark plugs.

After the sensor information computes, the ECM consults its spark map matrix to signal the ignition coil (31639-99) to spark the 12mm 6R12 plugs (32317-86A). This ignites and burns the incoming fuel charge to produce the best efficiency in terms of power. Emissions controls sometimes compromise this. Please see Chapter VIII: *Twin Cam Fuel Delivery*, section *Carburetion Integrated Ignition* for a full discussion on this topic.

Magneti-Marelli Fuel Injected Ignition

EFI is the acronym for electronic fuel injection. The ECM (electronic control module) links the ignition table or spark map with a fuel table that coordinates precise fuel delivery with ignition advance or retard settings.

Electronic fuel injection may seem more complicated than carburetion but is not. In fact, I think it is simpler. The Harley mechanic has to understand much of the physics that is necessary for carburetion to begin mixing the fuel and air as well as deliver it.

Magneti-Marelli EFI saw first use in 1995 on the Ultra Glide FLHTCUI. It discontinued after 2001 in favor of the more sophisticated and superior Delphi EFI. Softail models never saw use of MM EFI but began using Delphi EFI from the getgo in late 2000.

There are six main sensors that feed information to the MM ECM computer that contains the spark map matrix on timing when the spark plug should ignite. Using this system with a carburetor is a first for Harley. The sensors vary whether for carburetion or fuel injection. The seventh sensor is the Bank Angle Sensor or BAS (32495-98) that shuts ignition and fuel delivery if the bike tips over more than 55-degrees. BAS discontinues after use on early Twin

Cam MM EFI but returns on TLE and TLEU sidecar models serviced by Delphi EFI in later Twin Cam years. I visualize tipping a motorcycle sidecar whopping 55-degrees before the BAS sensor/switch turns off ignition and fuel delivery…scary, but welcome to say the least.

The MM sensors with their short form acronyms are:

1. TP-Throttle Position sensor (27271-95).
2. CMP-Camshaft speed and position (32496-99).
3. CKP-Crank or flywheel speed and position (32497-99).
4. BARO-Barometer or pressure altitude sensor (32424-98).
5. IAT-Intake air temperature sensor (27270-95).
6. ET-Engine temperature sensor (32446-99).

Five other components are required for the MM fuel injected Twin Cam ignition system:

1. Battery.
2. Ignition coil (single fire).
3. ECM-Electronic Control Module.
4. RFI (radio frequency interference) protected spark plug wires.
5. RFI spark plugs.

Please see Chapter VIII: *Twin Cam Fuel Delivery*, section *Magneti-Marelli EFI Fuel Linking Ignition* for a full discussion on this topic.

Delphi Fuel Injected Ignition

Delphi EFI was and is a huge improvement over the inefficient, too small Magneti-Marelli EFI. MM EFI looks mean with its dual runners, one for each cylinder but the throat sizing was a meager 38mm. Delphi began use between the late 2000 Softails and the 2002 touring models. The single induction module throat was larger than the MM throats growing to 46mm in 2007. I explore these areas in great detail in Volume II: *Performancing the Twin Cam* in Chapter IX: *Fuel Delivery.*

The Delphi sensors with their short form acronyms are:

TP-Throttle Position sensor (27629-01 and 32707-06) services the mechanical throttle actuator until the advent of fly-by-wire electronic throttle.

1. CKP-Crank or flywheel speed and position (32789-00, 32707-01, 32707-01A 32707-01B, and 32707-01C).
2. MAP-Manifold Absolute (or Air) Pressure sensor: 1999 to 2007 (32316-99).
3. TMAP-Manifold Absolute Pressure and Temperature sensor (32319-07) on 2008 to present models replaces the MAP sensor and adds a temperature function (IAT).
4. IAT-Intake air temperature sensor: 1999 to 2007 (27270-95 and 27381-06).
5. ET-Engine temperature sensor (32446-99).
6. The 2006 Dyna and all model 2007-to-present Oxygen (0_2) Sensor (FLT 27719-07 front exhaust; 27683-07 rear exhaust).
7. ETC-Electronic Throttle Control sensor (32305-08) introduces in 2009 and locates by the handlebar twist grip. Fly-by-wire electronic throttle control eliminates the need for manual throttle and idle cables.
8. BAS-Bank Angle Sensor (32495-98) found on TLE and TLEU sidecar models.

Five other components are required for the three main versions of the Delphi fuel injected Twin Cam ignition system:

1. Battery.
2. Ignition coil (single fire).
3. ECM-Electronic Control Module.
4. RFI (radio frequency interference) protected spark plug wires.

5. RFI spark plugs.

The cam position sensor discontinued circa 2001 because of timing chest teething problems that I will cover extensively in Chapter III: *Timing Chest Breakdowns and Solutions*. The pre-existing crank position sensor easily took over the logging of positions of internally timed-together components.

However, some part numbers for the various sensors change because they have different mounting on the Delphi EFI from those on the MM EFI and with the introduction of the TC96. Please see Chapter VIII: *Twin Cam Fuel Delivery*, section *Delphi EFI Fuel Linking Ignition* for a full discussion on this topic.

Electronic Control Module

The ECM or electronic control module is the main computer that runs the engine management system and thus EFI. All Evolution and Twin Cam Harley-Davidson's including carbureted models have an ECM but total engine management is the realm of electronic fuel injected models. Carburetor integrated ignitions, broach engine management but not to the level that EFI does.

The Twin Cam touring model Magneti-Marelli ECM locates under the right side cover along with the power 40amp circuit breaker (74600-97A, 72314-01) and fuel pump fuses, the Barometric Pressure Sensor if used, and the Data Link Connector for diagnosis with special EFI tools. The ECM will locate in different places over the Twin Cam years depending on model and year.

The power source for the ECM is via the battery and the main wiring harness through the 40amp circuit breaker or fuse, the ECM relay and the ECM fuse. The ECM basic functions are controlling the operation of:

1. The fuel pump.
2. Fuel injectors.
3. Ignition coil.

Again, the various *input* sensors provide the information to the ECM for constantly changing but programmed computer *output* fuel and spark delivery according to conditions at that point in time.

Primary Sensors

Suitable engine performance depends on three input sensors:

1. Throttle Position (TP) Sensor.
2. Camshaft Position (CMP) Sensor (Magneti-Marelli only).
3. Crankshaft Position (CKP) Sensor.

Secondary Sensors

Fine tuning engine performance but not absolutely necessary for basic running (limp-home mode) are three additional input sensors:

1. Barometric Pressure (BARO) Sensor (Magneti-Marelli EFI).
2. Manifold Absolute (Air) Pressure (MAP) Sensor (Delphi EFI)
3. Intake Air Temperature (IAT) Sensor.
4. Engine Temperature (ET) Sensor.

1999 “TWIN CAM 88 Fathead Specifications

Engine	Stroke, 45° V, air cooled, 88c.i 1450cc displacement
Bore/Stroke	3.750” bore / 4.000” stroke
Max sustained rpm/idle rpm	5500 rpm: idle rpm: 1000 rpm +/-50
Compression ratio	8.8:1 to 9.0:1
Torque	86 ft-lbs @ 3500 rpm, touring mufflers; 82 ft-lbs @3500 rpm, shorty duals.
Flywheel assembly	Straight press fit crank pin: inline male and female con rods; needle con-rod bearings; ball bearing pinion side; Timken left side, sprocket-shaft bearings (1999 to 2002).
Fuel delivery	38.5mm CV Carb or twin 38mm plate, Magneti Marelli Sequential Port Electronic Fuel Injection.
Ignition system	Carb-sequential, single fire, Map-N control; EFI-sequential, single fire, Alpha-N control.
Sensors	Crank Speed & Position (CKP), Cam Speed and Position (CMP), Throttle position (TP), Cyl. Head Temp (ET), Intake Charge Temp. (IAT), Barometric Pressure (BARO), Manifold Air Pressure (MAP).
Primary drive ratio	EFI – 24-tooth Engine Sprocket, 37-tooth Clutch. Carb- 25-tooth Engine Sprocket, 36-tooth Clutch.
Crankcase	Alloy, Vertically split, high-pressure die cast.
Cylinders	Alloy, high-pressure die cast, integral spiny lock cast iron liner. Liner thickness .247” (Evo .173”) O-ring seal.
Cylinder head	Aluminum, permanent mold with 85cc bathtub combustion chamber; single 12mm spark plug
Pistons	3-ring, hypereutectic aluminum with piston cooling jets
Oil system-pump	Twin-geroter, dual-scavenge, crank-mounted and driven internal oil pump, dry sump.
Oil system-pressure	Nominal 35 psi @ 230° F, 2000 rpm
Oil system-filtration	10 micron, filtered between pump and engine. (Evo, 30 micron between the pump and oil tank)
Engine weight	165lbs
Piston weight	416gm (Evo = 396.5gm)
Reciprocating weight	1634.5gm (Evo = 1501gm)
Piston pin diameter	.927” (Evo = .792”)
Crank pin diameter	1.670” (Evo = 1.250”)
Pinion shaft diameter	1.650” (Evo = 1.250”) @ main bearing
Bottom end inertia	280 in-lbs – sec^2 (Evo = 384 in-lbs –sec^2)
Cam system	Two cams, chain driven with spring-loaded tensioners.

Cam timing	Twin Cam EFI	Twin Cam carb	EVO EFI	EVO carb
Intake	4°btdc /35°abdc	4°atdc/43°abdc	0°tdc /22°abdc	1°atdc /34°abdc
Duration	219°*	219°*	202°	213°
Lift	.473”**	.473”**	.472-.495” varies	.472-.495” varies

Exhaust	40^{0}bbdc /2^{0}atdc	40^{0}bbdc /2^{0}atdc	44^{0}bbdc/10^{0}btdc	31^{0}bbdc /7^{0}btdc
Duration	222^0*	222^0*	218^0	204^0
Lift	.473 or .490"*	.473" or .490"*	.472-.495" varies	.472-.495" varies

* Engineers taught me these first specifications but then changed to 216^0/220^0 duration.

**Engineers taught me that the cams were .490" valve lift but I have only seen cams with .473" valve lift. Later lifts include .471", .474" and .484".

Please see Chapter VIII: *Twin Cam Fuel Delivery*, section ECM: *Electronic Control Module* for a full discussion on this topic. I will also explain the various EFI components and EFI specialty tools.

Fuel is Pressure Delivered

Fuel in an EFI system is kept under pressure in order for instant availability. Excess gas simply pumps back into the fuel tank. There is no lag time with EFI. Appropriately, the jargon for this is *injector on time.*

This contrasts with carburetion where atmospheric pressure differences draw in gas that must also vaporize. Intake manifold pressure is a measurement of the flow of air through the throttle body venturi and intake manifold. Suction from the descending piston on the intake stroke initiates the flow of air through the fuel delivery system. A carburetor creates a partial vacuum to draw fuel into the air. Carburetion is comparatively slow and inaccurate relative to the instant precise reaction time in a fuel injected system.

EFI Fuel Injectors

Electronic Fuel Injection delivers fuel under pressure by a pump to gizmos called fuel injectors. Injectors introduce fuel as a pressurized spray. There are two separate fuel injectors in a stock Harley engine, one for each cylinder. The longer an ejector nozzle holds open will determine the amount of fuel sprayed/squirted/injected, take your pick.

- Delphi (2001 to present) systems inject fuel onto the back of the intake valves just as they open and into their respective cylinders. Later Delphi EFI systems changed injector angles from 8^0 to a more efficient 25^0.
- The early Harley Magneti-Marelli EFI systems (1995 to 2001) spray the fuel onto the inside throttle body near the intake ports but this is silly since more efficiencies and speed develop by squirting it directly at the backs of the opening intake valves.

Twelve volts of electricity are sent to each injector as soon as the ignition is turned on and the starter button is pushed in order to start the bike. There is an electromagnet inside each injector. It *grounds* when a transistor inside becomes energized thereby opening the injector valve or nozzle. The ECM dictates injector pulse width, which is the time the injectors remain on squirting fuel.

Evolution and Twin Cam Engine Shared Parts

There are approximately 460 component parts in a Twin Cam engine. Very few parts make the crossover from Evolution to Twin Cam. Many of these common parts change as the Twin Cam year's progress:

1. The Timken sprocket shaft bearing sets change to a roller bearing in 2002.
2. Valve guides (4) remain the same from 1984 to 2004.
3. Valve seals also change from a press fit onto the top of the guide to one incorporated into the bottom spring collar.
4. By 2005 the Twin Cam begins to use valves with thinner stems reducing valve train weight and inertial drag. Intake valves (2) use thinner stems beginning late 2004.
5. The dual cylindrical valve springs replace with the single Beehive valve spring over two years beginning in 2002 and complete by the end of 2004 depending on model.

Only 16 component parts find use throughout the Evolution era and into the Twin Cam era as late as 2010. The years in use may predate the Evolution engine and may in fact go back as far as to the Knucklehead era; may originate with the OHV Ironhead Sportster in 1957 or the Evolution Sportster in 1986. It is amazing to observe the longevity of use of some Harley-Davidson parts. An engine pinion shaft Woodruff key (23985-12) that began in use in 1912 and the crank pin Woodruff key (23985-18) that began use in 1918 both ceased use in early-1981. The student of Harleyology will begin to recognize crucial year changes and thus component part changes by part number suffixes such as -36 (Knucklehead); -48 (Panhead); -52 (K Flathead series); -57 (Ironhead Sportster); -66 (Shovelhead); -83 (Evolution); and -86 (Evolution Sportster) to name a few.

Designing the Twin Cam "88"

A Reusable Investment for Harley-Davidson

The technical expertise learned from designing the Twin Cam 88 is an investment in the future for the Factory as all new designs will flow from a model that is diametrically opposed to the way things were in the past.

Take the development of the Evo engine prior to 1984 as an example of the old way of development. There was no thought beyond the motor itself. There was no platform for future development to evolve. Specifically, the introduction of Screamin' Eagle parts was an afterthought. A year down the road, Harley started to introduce a small unimpressive array of performance parts. Only the Evo Screamin' Eagle air breather kit could initially stand up to anything the aftermarket produced. For fifteen years now, the aftermarket has dominated high-performance for the Evolution.

It is not going to happen this time. Harley has learned the lessons of the past well.

The Factory planned for engine durability and reliability, compliance with emissions and noise controls and a platform for possible ongoing changes.

- Increased performance and better handling through rigidity were also priorities.
- Introduced in tandem with the Twin Cam motor is a comprehensive package of high-performance parts to complement it.
- This time it will be the aftermarket playing catch-up.

Another problem for the aftermarket is that if there is not a series of screw-ups (except for a weak timing chest) to capitalize on as there was with the Evo. This was all taken into account in the original design. Correcting any mistakes in the beginning hopefully will not result in any problems in the end. As we will see, this turned out to be largely true but still was a little too optimistic. I am going to compare the design processes utilized with the Evolution relative to the Twin Cam. The former design process used on the Evolution was:

Design it … Build it ... Break it … Fix it.

This is not a systematic approach, which views every part in its relation to other parts. It deals with one broken part at a time. Engineers test the engine until something breaks. They then fix that part not knowing what is going to break next, and on it goes until confidence builds that everything is going to work properly. This is the main reason the Evolution had ongoing problems like weeping gaskets; weak case construction, pulling studs, etc. There was no model to help predict and analyze weak parts that did not break during design process.

The design process for the Twin Cam sought to eliminate problems before production. Prior to building the engine, a three-dimensional computer design is modeled and analyzed.

Design it … Analyze it …Test it … Redesign deficiencies … Build it

I know; it also took me awhile to get my mind wrapped around this concept. Bear with me, and it will become easier to understand. You may have seen those 1990's Chrysler ads on television where the three-dimensional model design schematic rotates with different colors. H-D now uses the same process. The procedure involves building the vehicle first on a computer. Therefore, when a part breaks after the bike goes into production, the question becomes what is wrong with the model, not the part. Why did the computer model not predict the failure? Fixing the computer model, in turn, fixes the part through redesign.

This is going to get easier to understand. It is confusing because the old way seems more real while this is new, and it is opposite to what we already conceptualize. The three-dimensional computer model offers full analysis before building the first engine. It analyzes structural integrity such as weak motor case areas as well as component fitment like piston-to-cylinder tolerance from differing perspectives. The different types of analysis are:

Static Analysis

This involves analyzing stress such as connecting rod stretch. Yes, con rods will stretch in an engine. They thrust up and suddenly pull down millions of times over the life of a motor.

Dynamic Analysis

Examples of this are engine performance in the chassis from say 0 mph to 60 mph. One illustration of the computer's investigative capability is predicting the stability of the valve train under the forces that it must contend with. Vibrational forces are another example that Dynamic Analysis will investigate.

Description	Part Number	Years in use
Sprocket shaft bearing set	HD-9028	1969 to 2002
Valve guides (4)	18112-92 standard	1984 to 2004
Intake valves (2)	18074-83A	1984 to 2004
Intake valve seats (2)	18020-83	1984 to present
Exhaust valve seats (2)	18011-86	1984 to present
Valve springs (4 sets)	18202-83/18210-83	1984 to 2001
Valve spring collars (4 sets)	18219-83/18222-83A	1984 to 2001
Valve collar keepers (8)	18229-83	1984 to 2001
Valve seals (4)	180001-83B	1984 to 2004
Rocker arms (2)	17360-83A	1984 to present
Rocker arms (2)	17375-83A	1984 to present
Rocker arm bushings (8)	17428-57	1957 to present
Rocker arm shafts (4)	17611-83	1984 to present
Short head bolts (4)	16480-92	1992 to present
Long head bolts (4)	16478-85A	1985 to present
Spark plugs (2)	32317-86A (Evo XL)	1986 to present
Oil pump relief valve	26400-82B	1982 to present
Exhaust port studs (4)	16715-83	1984 to present
Lower pushrod O-rings (4)	HD-11145	1984 to present
Middle pushrod O-rings (4)	HD-11132	1984 to present
Center pushrod tunnel cap (4)	17945-36B	1936 to present
Pushrod tunnel spring (4)	17947-36	1936 to present
Engine case dowel O-ring	26432-76A	1976 to present
Seal intake manifold	26995-86B	1986 to present
Center breather screw	29269-83A	1984 to present

[1] Initial crossover 1998 to 1999 CV Kehein carburetor and 1995 to 2001 Magneti-Marelli EFI fuel delivery mechanisms are the much the same in the Twin Cam except for minor differences from the Evolution models.

Finite Element Analysis

This analysis loads up the computer model to demonstrate the structural weaknesses of an engine that does not yet exist. For example, a weak area in an engine case will glow red on the computer screen. If this technology had been available to Harley before 1984, there would never have been any engine case breakage or weepage.

On the other hand, would it? I am suspicious because if we jump to the timing case boondoggles that plagued an almost perfect engine from 1999 to 2006, these problems took a long time to resolve. Perhaps initial denial of problematic conditions and limited warranty to resolve some issues was less expensive than implementing Finite Element Analysis possible solutions. Alternatively, maybe the analysis took seven years to institute a promising correction. Fascinating, is it not? This is a major reason the Fathead motor should have few problems, if any.

Again, jumping into the future, it is easy to make the case that the Twin Cam has had the fewest problems of any H-D engine. Do not get me wrong. The Evolution was a remarkable engine built and designed the old way. However, just think of how much more remarkable it would have been if designed under this new system.

1. This analysis identifies weak sections of assembled components under load.
2. The computer model evaluates how parts interact with each other.
3. For redesign purposes, the computer adds up all the stresses and forces to show the weak points in the current design model.

Computational Fluid Dynamics (CFD)

This just gets more exciting. CFD analysis examines areas like port flows and engine breathing. Can it get any better?

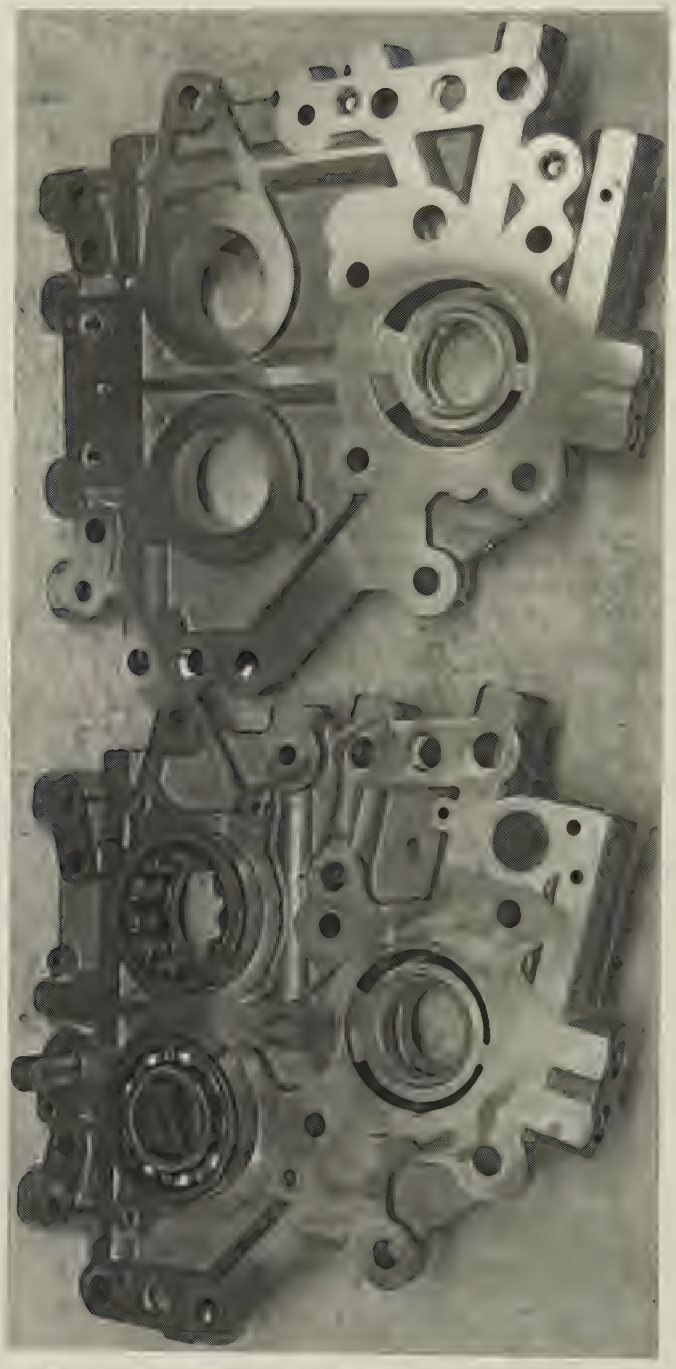
Heat Rejection Analysis

This is a thermal balance study, which means it is a predictor of heat flow characteristics such as heat dissipation. Heat dissipation or heat exchange is layperson terminology. Professionals refer to this concept as heat rejection. Heat rejection analysis resulted in 60% increased head and cylinder finning on the Fathead. This is a long way from temperature probes in a wind tunnel. Again, all of this occurs before building an engine!

Conclusion

1. All gleaned analysis is from the computer model before a part is manufactured.
2. Once done, building a prototype to test, therefore validating the model is the next step.
3. If a component breaks, the question becomes; what is wrong with the model not the part.
4. The new way goes in a circle like the old way but in the opposite direction.

The old way does not evaluate the whole. It seeks to:



Comparing a Twin Cam Late-2000 to 2006 and 2007-to-Present Cam Support Plate

Pictured on top is the 2006 Dyna and all 2007-to-present TC96, TC103, and CVO 110 inner (inboard) side cam support-plate (25355-06). An earlier 2000 to 2006 (except 2006 Dyna) TC88 3rd generation inboard cam-support-plate (25267-99B) is pictured on the bottom. The cam support plates are sideways in the picture. In use they situate (rotate picture clockwise) so that the pinion shaft bushing sits underneath the two outboard cam support bearings. The pinion shaft bushing feeds oil into the pinion shaft it houses for delivery to the bottom end. The oil pump bolts to this side via four bolts, supported and driven by the pinion shaft. The oil pump-bolt holes are evident around the pinion bushing. Beside the bushing and two of the bolt holes is an oil return hole in the cam support plate. Location of this oil return hole has changed from the early to late configuration support plates, as has the oil passage it serves. The oil pumps and support plates are not interchangeable for this and other reasons. The outboard cam end journal-support bearings locate above the pinion bushing. The 1999 to 2006 bottom pictured ball bearing (H-D 8990A) supports the front cylinder camshaft's outboard journal. The 1999 to 2006 rear camshafts outboard journal roller bearing (H-D 8983) sits above. The inboard cam end-journal bearings (not shown) are located in the engine casing separating the bottom end and timing compartments. The earliest cam support plate (25267-99), utilized two ball bearings. The rear cam ball bearing is subject to stresses that cause it to break down and sometimes disintegrate. H-D corrected this problem by using a ball bearing to support the front outboard cam journal and a roller bearing to support the outboard rear cam journal as shown in the picture. In 2006 with the Dynas and in 2007-to-present Twin Cams, H-D eliminates traditional bearings altogether to support the outboard cam journal ends. H-D increases the diameter of the cam journal ends and uses *parent* material to act as parent bearings. In 2011, the Motor Company also eliminates the pinion shaft bushing in favor of parent material. In other words, the cam support plate itself now fulfills the function of support bearings and bushing. Cost effective, I am sure; however, I prefer actual ball and roller bearings with a pinion bushing.

Run … Break … Analyze individually

The new way evaluates separately and in conjunction with the whole.

Analyze … Run …Validate individually and in totality

The complete design and analysis occurred before Twin Cam engine construction. The Evolution fixed problems after the fact as they occurred in an ongoing process. Theoretically, the Twin Cam Fathead should have far fewer teething problems than the Evolution.

The development and investment in this new technology by Harley-Davidson occurred at the same time as the development of the Fathead TC88. It was necessary to develop this technology in tandem to make the Twin Cam a reality of durability and longevity.

This capability is supplemented with new investment and thus the process to develop the Twin Cam in state of the art acoustics labs and emissions as well as dynomomneter facilities not available for previous engine development. The initial investment will allow the use of technical expertise, learned on this project many times in the years ahead.

The Factory is spending hundreds of millions of dollars, investing in the future, at every level, including employee development, technology, machinery, plant facilities, becoming dominant in racing and, of course, new product development. Wherever I went, from the secret places to the public facilities, this was very evident in every aspect of Harley-Davidson operations. The legend is going to continue in a big way.

H-D was building about 82,000 units a year when Kenny Sutton, vice president and general manager of Harley-Davidson's powertrain operations, started with the Factory. He has ramped this up to 135,000 units presently in 1998, and he is working hard to get to the magic number of 200,000.

Mr. Clean

Kenny, who I call "Mr. Clean," builds motors and transmissions at both the Capitol Drive and Pilgrim Road plants in Milwaukee. No, he is not bald, but he is clean. He is *The Man.* Can you imagine the responsibility of producing 450-motors and transmissions per day, reliable motors that do not screw up? Think about it. He has the job of increasing that number, for every day and every week of the year. In addition, he has to build the new Fathead in tandem with the beloved Evo and all those Sportster motors, too. To top it all off, he will also be in charge of the *new* Sportster motor that will be coming onto the production line in the future. As I look back with 2010 eyes, the Evolution Sportster did not go through radical redevelopment although rubber mounting in 2004 was a milestone in vibration control.

My eyes scanned the Pilgrim Road plant as Jerry Wilke, Harley vice president and Buell president, and Kenny showed us their manufacturing prowess late at night. Up since 6:30 a.m., learning the new technology, my fellow *American Iron* team compatriots, Chris Maida and Buzz Kanter, dared not get tired because these enthusiastic Harley workhorses sure did not.

Micrometer Eyes

Looking at bins full of Fathead flywheel castings, head blanks, and the shorter, fatter barrels, I was on the lookout for prototype Screamin' Eagle upgrade parts. Kenny looked at me inquisitively when I remarked on some stock Fathead barrels. "I am just checking for some taller stroker or larger diameter bore barrels," said I. "Whaddya got, micrometer eyes?" shot back Kenny. Well, as a matter of fact, after rebuilding Harley motors over twenty-five years you do get a feel for a couple of thousands-of-an-inch here or there. Hey, Kenny was warming up to me. He found a pal in the middle of the night who liked what he liked…building motors.

Bright White

Kenny, given the huge job of ramping up production; ensuring quality manufacturing; and constantly increasing production, smiles broadly about his job, his accomplishments, and what he has planned. He has the endearing qualities of all the top wrenches. He loves cleanliness, he hates oil on the floor, and he likes lots of light. His executive compatriots think he carries this a bit far, to the point of neurosis. I agree with Kenny's thinking but I also think they hire a person just to hide the paintbrushes and the white paint from Mr. Clean. He loves having hundreds of thousands of square feet of ceilings painted bright white. When the ceilings fade a little, off he goes, brightening them up again.

The lighting is not the soothing kind that puts one at peace with oneself but reflects brightly off the ceiling. "Drop a small part and I want to be able to find it," he rationalizes.

"We build motors, damn fine motors, and you need the light, the people, and the technology to do it"

The H-D Logo Sign Instills Pride

"Ahhh, what about that \$85,000.^{00} sign out front?" queries Jerry with a smiling jab. "Worth every penny," counters Kenny. "It shows our pride and it instills pride. It is the first thing our workers and guests see going in, and it is the last thing they see going out, a big, beautiful, quality chrome-and-black Harley-Davidson logo". This guy spends money and I mean big money. However, he has a rationale for every penny spent.

The Engine and Transmission Plants

He is taking the plants into 2000 and beyond. Capitol Drive is 350,000 square feet and it will be the build-center for all the Sportster motors. There is also 1,000,000 square feet of building space at Pilgrim Road. No, I did not tack on a zero. A million it is. "Got a real good deal on that baby," enthuses Mr. Clean. "Know how hard it is to sell a building that big?" "Plus you were able to paint the ceiling before moving in the machinery," Jerry interjected.

Undeterred, Kenny continued. "We are only going to use half the building for the Evo and Twin Cam motors and transmissions and keep the rest of the space for future ramped-up production." Kenny Sutton lives in the future while perfecting the present. The place is so big that thirty-five tractor-trailers can park inside at a time and turn around. This is necessary to keep the motors moving out to the York facility for motorcycle assembly and to keep the supplies rolling in. Kenny has loading docks or will have at his two plants on three sides of each building in order to keep product moving in and out efficiently. Why deliver to one side and have to drag material and parts to the other side? It is disruptive. Smooth and timely flow with a minimum of disturbance is the way Kenny works.

"By the way, those machining centers are \$3,000,000.^{00} apiece," relates Kenny. "There are a lot of them going in, and they are state of the art for the production of our new motor and the continuation of the Evo." The building was the inexpensive part; what is inside costs the real money. The robotic computer-programmed machining centers work tirelessly while being monitored by the Factory workers who do their own quality control. Tracing every part back to the person who made it helps to ensure quality control. Computers select the frequency of inspection depending on part complexity and past quality records. Measurement of parts is in on-site sterile labs with a variety of tools, such as numerical light measuring sensors that compare reality with the computer model.

Cold-Testing New Engines

Engines are cold-tested with a system that can even tell if a head bolt torque is to specification. Kenny explains: "Why test an engine when there are explosions going off inside the cylinders? The noise and all the commotion when using a hot test just hides problems we can detect with this cold method. Vibration sensors are hooked up like that in a medical lab to determine bodily functions." This testing procedure lets the computer decide if it meets Harley's ever-increasing high standards.

Nuking parts for precision heat-treating, new technology for making quiet full- contact-ratio transmission gears, and the best powdercoating I have seen, are only a few areas that H-D has addressed in its plants.

Green is Good and Red is Bad

Kenny is one organized person. His eyes sweep the Factory, taking it all in. There are two lights…one red, one green…over each piece of machinery. When they are all green, Kenny is happy. When red, a problem exists, and Kenny becomes unhappy, with a problem to solve. I never saw a red light go on in either facility. Problems are resolved during production so that they do not compound. Ignoring nothing while solving problems, this is what efficiency and quality are all about.

Green is Outta Here

Upgrading machinery is ongoing. Anything painted green is about to be replaced with better equipment. The replaced equipment goes elsewhere to replace still older equipment. There is nothing wrong with the machinery as it shunts down the food chain, replaced with the state-of- the-art robotics and tooling.

Everything is replaceable except the people. Jerry intones; "People are our greatest asset. We don't replace or shrink our family, but we sure encourage them to upgrade their skills."

With a glance, Kenny scans the hundreds of thousands of square feet of production that is easy to see under those white ceilings one last time for the night. We move on to the Capitol Drive plant just a few miles down the road. Once there, as the night moves on, Kenny demonstrates his flair for solving problems as nothing gets in his way.

Islands Reduce Vibration

"See this floor, Don. There's a problem"

"What's that?"

"There's a basement underneath."

"So?"

"Heavy machinery, Don, the floor wasn't strong enough"

"So?"

"Got a bridge builder in; we built a bridge under the floor."

"Okay."

"Had another problem; the tow motors make the floor vibrate ever so slightly, which is bad for this sensitive precision machinery"

"So what did you do, Kenny?" I finally realized my function as a foil for his story.

"Cut out an island for the whole production line, which is held by the bridge and separated from the aisles where the tow motors are."

His pragmatic solution blew me away. Then Mr. Clean started again with his broad smile.

"We had another problem, Don."

"Go on."

"This machinery requires a lot of oil and hydraulic pumps and lines. We were able to put them all in the basement."

"Sounds like a great solution, Kenny. What's the problem?"

"Oil, leaking oil, it's hidden in the basement. I cannot see it when it dirties the floor. I don't like any kind of dirt in my factories."

"Spoken like a true motor builder, Kenny."

“We solved that at Pilgrim Road. You can see the oil if it starts to leak. We put the hydraulics right up front”.

On the night went. I commented on their dedication on being in the plants at all hours and their ability to call many employees by name. “We cannot expect our employees, an extended family, to take pride and work hard unless we are proud and we work hard; but, Don, look around, you would not call this work, now, would you? Where else would you rather be?” [3] I cannot argue with that.

Screamin’ Eagle is Flying High

The Fathead is a great engine and serves as a platform for even greater possibilities. Ensured is future engine development, as is increased power, even with ever-stringent emissions and noise controls. Just from a pure horsepower point of view, it will be amazing.

The Twin Cam era is where Screamin’ Eagle is gonna scream!

We could hardly wait for our meeting with Pete Amenda, general manager of performance products, because it was obvious to us that the Twin Cam platform just begged for performance upgrades. I am used to talking to factory reps and dealers that really do not know too much about horsepower and how to achieve it. I do not fault them since they never seem to view performance as their domain. Well, that is all going to change. Pete knows his stuff. He is no slouch in this arena, and he has the inside track with the engineers.

When the Evolution came out in 1984, Screamin’ Eagle performance parts were an afterthought and not on a par with what the aftermarket had to offer. With engine conceptualization and the new design model philosophy, high-performance parts became an integral part of the plan. This is why the Fathead is a platform. It is a launching pad for progressive change.

There is enough meat on this baby to allow for some dramatic horsepower increases.

Leaving the ultra-conservative 4.000” stroke alone and taking the barrels out to $3\ ^{31}/_{32}$” from its stock 3 ¾” bore will alone increase the cubes to 98.5c.i (1625cc). Combine a 3 ⅞” bigger bore with a 4 ¼” stroke like the Evo’s and we are up to 100.2 cubic inches or 1642cc. Moreover, a still safe 4 ½” or 4 ⅝” stroke increases proportionately again to 106.1c.i and 109.1 cubic inches respectively. As it turns out, larger bore increases become possible producing 124c.i engines with great longevity.

The soon-to-be introduced “for race only”-labeled override kits for fuel injection and aftermarket exhausts that do not have to contend with emissions and noise controls will give even more gains. However, Harley and Screamin’ Eagle are trying to make their high-performance parts not only deliver the beef but also comply with pollution controls wherever possible. That is their aim. I feel that H-D knew it had a marketing window before the government really began cracking down on performance up selling with EPA-compliant stock bikes.

The aftermarket goes ‘Ouch!’

Now, one has to remember that the Fathead has incorporated many functional high-performance aspects into this bulletproof – as far as we knew–engine already.

It is obvious that the Fathead is 88 cubic inches, which translates into 1450cc. However, some other built-in efficiencies that also result in performance increases are:

1. Anti-reversion step torque valves for low-end power built right into the exhaust ports.

2. Torque support arms are outdated also since the extremely rigid new transmission box-motor juxtaposition negates their need.
3. The barrels are already big bore at 3 ¾" up from the Evo 3 ½".
4. Compression increases also.
5. Carbureted models will be faster off the line because of a slight primary gear reduction.
6. ECM spark matrix 12 x 16 cell maps initiate when the plugs go off. Fuel delivery coordinates with ignition on EFI models.
7. The Fathead uses a single-fire ignition system, which eliminates the wasted exhaust spark inherent in the traditional dual-spark setups.
8. The stock bathtubbed combustion chambers are an aftermarket biggie that is standard equipment on this engine.
9. Even the newly styled, pointed-at-both ends, cool-looking air cleaners provide higher airflow induction.
10. Straighter pushrod angles add mechanical efficiencies.
11. Even the redirection of top-end oil spilling back into the timing chest instead of the crankcase that causes inertial drag on the engine flywheels adds to the stock oomph.

Most of these incorporated features were formerly the domain of high-performance upgrades.

The Screamin' Eagle Plan

We were provided with obvious planned performance upgrades but comprehensive information was lacking as was the full scope of the Screamin' Eagle program. As of 1998, they were:

1. Carburetion includes jetting kits and Thunder Slides.
2. EFI will have override kits.
3. Three styles of performance manifolds are in development in.
4. Four air cleaner kits with even more area in the filter for flow will be available along with retrofit air cleaner kits for the Evo.
5. A performance clutch spring, introduced on the 1998 models, will transfer more ponies back through the powertrain.
6. Different upgraded and colored coils from stock will add cosmetic performance items.
7. Work is proceeding on big-bore 1550cc barrel kits with a thinner sleeve. This has turned into a reality. However, the cylinders are bored-out 1450cc stock ones, hence another reason for the very thick stock liner.
8. The stock 85cc combustion chamber will effectively become relatively smaller with these barrel kits, producing a Stage I kit with a 10.5:1 compression ratio and a Stage II kit with a big 11.5:1 ratio that is unheard of in an Evolution engine.
9. Piston kits with the above compression ratios are also going to be available with the 1450cc Fathead. In retrospect, the Screamin' Eagle piston kits have been excellent both in performance design and quality. As it turns out, these kits moderated slightly by the time they came to market.
10. Cams will be offered in whopping big sizes, such as .575" lift, .600" lift, and a .640" lift as well as conservative sizes. Since the stock cam lift is .490" on prototypes and .473" on production bikes, this is big stuff. It is a brave new world for Screamin' Eagle.

11. Performance cams will lead to roller rocker arms, performance valve springs, valve guides and, of course, pushrods.
12. Complete upgraded ignition kits will be marketed. It just gets better. The ignition packages will tie to the different compression ratios and cam packages.
13. Rpm limiters of 6200, 7200, and 7500 will correlate also, although this is for the testosterone set since the engine should not rev this high because it is pushrod-operated.

This advance development approach is a huge departure for Harley-Davidson and Screamin' Eagle. It is a different world built on the platform of the TC88Fathead. The performance examples give an indication of how good this motor is to accommodate these parts. Some of these upgrades are drag strip technology when used in the Evo. However, they will function normally on the street with the Fathead.

Speaking of the Evo...

Speaking of the Evolution, there are around a million of them out there. Everyone has constantly assured me during my visit that the Factory is not giving up on the Evo. This was to soothe the resistant-to-change Harley public. The 1999 Softail series lineup use the Evo engine, as the Dynas and the FLHTs introduce the Fathead.

The TC88 Dyna Glide is the new de facto hot rod Harley. This results from the bigger engine, the improved new rubber mounting system, and the handling that will evolve from the rigid motor-transmission combination.

In conclusion, a Screamin' Eagle aftermarket parts program was nonexistent during the Shovelhead era. It was an afterthought with the advent of the Evolution, but Screamin' Eagle parts development is fully coordinated and integrated with the Twin Cam concept, design, and, finally, the build.

Milwaukee's Secret Race Facility

Then we were taken to a secret facility in a small town (I promised I would not reveal the location) outside Milwaukee. However, I will say that it is in an industrial sector on the last street in the last building. Like everywhere, there litter scattered in the surrounding fields. The nondescript building had anonymous signage and for all intensive purposes looks pretty much deserted.

Inside was another story. It was well lit, super clean, and well organized. The Factory Race Team's head honchos, Steve Scheibe and Art Gomper began to teach us about the VR1000.

Three race bikes, three fresh motors on the floor and ten more in various stages of testing and construction allowed for a thorough examination. Like many of the hardcore, I never paid much attention to racing. These guys converted me. Now I can hardly wait to see the VR kick serious ass and, along with the Buell, possibly rack up some championships. Who would ever have thought Harley could begin to compete with the Japanese, the almighty Ducati and Bimota?

Why mention racing when we are talking about new bikes for the street? Well, racing teams are marketing tools for selling the manufacturers' bikes. Harley also uses its highly competent team to develop new product for you and me.

Then we met the person that everybody thinks screwed up the VR 1000 wheel change in the pits the previous year (1997) at Daytona. The truth was he didn't screw anything up. In fact, he risked serious injury in a real bad situation. It is very dangerous to take a wheel off a bike that is doing some serious spinning because there is no clutch. This is what he tried to do in a twelve-second pit stop. In spite of this malady, the VR held second place for quite awhile with a blown clutch. When the gods smile Harley's way, the VR could take Harley to the top in what many, including myself, thought impossible.

As I drifted about feasting my eyes, I talked valve lifts and stuff with the mechanics. I could not understand the reason for our admission into this facility. Anyway, I was happy to be there. I wandered into a separate room with special machines compressing and releasing valve springs to a predetermined level. Different machines were going at different speeds and allowing the springs to release to differing heights. Fascinated, I began to study them and figure out what was going on.

Looking impatient, Buzz came in with one of the race team honchos. "What is going on? Why are you spending so much time in here Don?" "Well, Buzz, they are testing different strength and metallurgy, different lift, and different type valve springs to match up with the most appropriate cam designs for the race bikes. Valve springs control valve float and bounce along with cam profile duration. They are testing for the right combinations. This is the kind of stuff that will let one bike win out over another, all factors being equal. Now, Buzz, look here, I will show you something…"

The whole tone of friendliness in the facility changed in a millisecond. Panicked and accusatory Japanese bike spy related statements quickly followed by some of the H-D race team. I guess it never occurred to the Factory people that a writer might also be a proficient and thinking mechanic with some graduate physics background. I was reminded of my secrecy agreement during my reprimand for figuring stuff out as they began to shuffle us out the door.

"Be cool, man. I am loyal to H-D. I do not need a secrecy agreement to keep confidential information to myself. I am on your side!" Everyone breathed a sigh of relief. We turned it all into a bit of a joke, and then they showed me the race trailers and the tooling in them.

I knew I was now on probation because I had the capacity to learn too much. This was a drag. I had been waiting for an opportune moment with the proper person to inquire about a little ditty Buzz and I had spotted earlier. The famed and very secretive Nova project that AMF instituted in the seventies to bring Harley-Davidson into the twentieth century is an extremely interesting story. This Harley-Davidson prototype featured a Willie G. design radiator and liquid cooling with overhead cams in a 60-degree V-Twin engine. It also had the first five-speed transmission and rear belt drive. I dared not mention the prototype Nova we had seen stuffed into a dark corner in the Juneau Avenue building. Please see Volume III: *The Evolution 1984 to 2000*, Chapter I: *The Gang of 13*, section, *The Ultra Secret Harley-Davidson Nova* for extensive information on the bike that came close to revolutionizing the future of this venerable company.

The $1,000 Lunch

I am not a fancy person. Pretentious restaurants are not my thing. So, there I was, being taken out to lunch by three H-D vice-presidents and Jerry Wilke, the president of Buell, to this very nice restaurant overlooking a wide expanse of nice country scenery. I am still dressed in my jeans and running shoes unlike everyone else in the luxurious setting.

The two hours went by quickly as those who knew how to work lunchtime into a productive work session engaged me in a series of conversations. They quizzed me on my views of pricing the Twin Cam. "Could it be sold for more than the Evos?" "Sure, H-D always goes up in price," I replied

"Should it be reduced in price to curry the Harley consumer's favor?"

"That would be nice," I said. "However, I think it's unnecessary since the quality was very evident to me".

"Would the riding public view the Twin Cam as an upgrade to the Evo?" I started to catch on; I just never thought my opinion would matter much to these masters of marketing. They could tell I was in touch with the average H-D rider. I started thinking more about my answers since we were not having idle conversation. "I don't think you should rise pricing much, if at all," I said. "While I am extremely enthusiastic and positive about the Twin Cam, I have been educated intensively and can see the investment and the many improvements the Factory has made. The riding public will be concerned about engine shape and the ties to traditionalist styling. The stylistic change is not that much, which is good. It will take a few years for the consumer to learn even close to what I know, even if they are interested. The rider is very loyal to the Evo after enduring the Shovel years. I think I would let the Twin Cam sink in with the public in terms of its reliability and relative speed before I made any sudden changes like hiking the price right away."

On it went, with the gentle probing from every angle of the marketing formulation. When they were satiated, the conversation began to change into the second major theme of the lunch.

The Buell

Jerry sensed that I did not like the Buell. It was not a question of that; the Buell just did not fit in with my personal concept of what a Harley should be. We politely parried back and forth. He was always smiling and gracious.

Then he nailed me. "Have you ever ridden one, Don?" "Nope," I replied. He had me in one fell swoop. "Well, why not ride one Don, before you make up your mind." I interpreted this as why not try to open up your closed mind. "I took the liberty before lunch of calling Toronto Harley-Davidson. They will deliver a Buell to you to ride around as long as you like. Let them know when it is convenient for you, Don," Jerry said soothingly, trapping me with his dexterity. "Done deal, Jerry," I replied.

It was time to go back to the Factory to learn more. These people start early, work in differing formats all day long, and go home late. I grabbed the bill to throw my share in, when it was politely taken away from me and paid for by the corporate expense account. I was taken aback a little because lunch cost close to a thousand bucks, which is certainly out of my league. I asked, "Do you guys come here often?" "We can't afford to eat here," came several replies simultaneously. We were all first-timers. "So, why did we come here?" I asked. "Well, we thought you would like it, Don."

Riding the Buell

I got the Buell on my return. It felt awkward, as I had mostly only ridden Harley Big Twin choppers until that point of my riding career. As always, on a new bike I ride cautiously for a mile or two, checking out handling, brakes, and stuff.

I gently but progressively used the front brakes, amazed at their stopping power compared to what I was used to. Finally, I grabbed a handful. Big mistake, as a bunch of stuff happened all at once. First, there was intense searing pain as my body slid into the gas tank squishing my poor testicles. Then I had to grab the handlebars forcefully to stop my body from going over them. Thirdly, the rear wheel had gone into the air doing a reverse wheelie so I had to stabilize the bike so I would not fall over.

Okay, the Buell had now taught me respect, so I paid attention for the rest of my test ride. It was fast; faster than any Harley that I had ever ridden, including my big-inch strokers. As I got used to it, the Buell handled better than any other bike I had ever ridden.

Wow! I was impressed and began writing an article about what a wonderful product H-D had engineered in tandem with Erik Buell. A friend dropped by who wrote bike reviews for the local Saturday newspapers. I enthused endlessly about the Buell while he increasingly looked more quizzical.

"Don, have you never ridden any of the Japanese or Euro super bikes?" "Of course not," I replied. "You know that."

"Well, I think you'd better try one or two out for comparative purposes."

"Whaddya mean?" Letting me down gently, he went on to explain. "Yes, the Buell is fast relative to other Harley's but slow compared to its peers in the super bike category. Yes, it brakes well compared to other H-Ds but not as good as its peers. Yes, it handles great compared to what you are used to but only okay compared to its competitors, and, yes, it is designed nicely but not quite as nice...."

"Now for the real problem", he intoned. "As with all Harley's, the Buell is far too expensive when compared to its competition." "Oh!" I replied, all the steam going out of me. Poor Jerry, I thought as I shelved the article.

This was written in 1998, but, you know, nine years later while riding across South Africa at 85 mph with local riders, some of who were on Buell's, I regained my former awe. South Africa is the hub of Buell acceptance. The bike is very popular. H-D of Johannesburg is reputedly the largest Buell dealer in the world. After watching and riding with them on the highways, I have to say one thing, on the great highway expanses of South Africa, the Buell's constantly passed me, often operated with only one hand, as if I were standing still. At a rest stop, I incredulously asked some of the riders how fast they were going. The answer was anywhere between 140 and 160 miles per hour. I was impressed all over again. Maybe the foreign bikes are better, I do not really know, but Buell's sure are impressive to an old Harley Dawg like me.

Thanks to my Teacher(s)

Our teachers in 1998 during our intensive education about the new Twin Cam 88 were the hands-on engineers that designed and are about to build this remarkable powerplant.

Bob "Koby" Koblarz, chief engineer of the powertrain division, is patient with me. He takes an interest in me and helps me through difficult concepts because he sees my eagerness to learn.

1. Bill Davidson, manager of motorcycle product development, has an emotional and historical bond with the company that bears his name. He has a sense of history and devotion to Harley-Davidson. He is "responsible for making sure we are catering to the customers' desires; listening to the customers."
2. Kenny "Mr. Clean" Sutton, who actually runs the plants that manufacture the Evolution engines and will be building the Twin Cam engines and transmissions, is dedicated and a fine teacher in his own right.
3. Jerry "Mr. Smooth" Wilkie has an abiding love and fervor for the product. His enthusiasm and excitement rapidly become your own.
4. Other engineers and H-D people constantly intervened, teaching us their specialized areas of expertise.
5. Finally, but most importantly, is Skip Metz, to whom I wrote the following thank you letter after our visit to Milwaukee.

6. I have discussed the key people we met with but we also talked to machinists on the Factory floor and a myriad of other workers who gushed with anticipation about teaching us when the brass told them we had security clearance. No one was gushing more than we were when it came to learning the new knowledge.

Skip Metz
Harley-Davidson Motor Co.
11800 West Capitol Dr.
Wauwatosa, WI USA
53225-5527

Hi, Skip:

I cannot say enough about how impressed we were with you and your project.

Sorry for making you go through everything three times, but it was worth it in the end.

I am able to conceptualize the different systems, such as oiling and breathing, which means I can adequately describe them. I now feel very familiar with the project after our sessions.

R. Teerlink, Harley president at the time of writing was in Toronto for a speaking engagement yesterday, and I told him how impressed I was with his support team, including you and Koby, I did not mention the project specifically (as required by my secrecy agreement) but talked in generalities about the great work you guys do.

I quote you in the main article a few times about pain in the beginning making success worthwhile in the end.

I have written five articles of about 13,000 words, and it was 100 percent positive. I walked into that room with about twenty Evo defects in my brain, and you addressed every one of them.

It is very impressive!

Thanks again
Donny PetersenHeavy Duty Cycles, TorontoWriting for *American Iron Magazine*

The Harley Fantasy Trip 1999

"How would you like to ride six different 1999 Harley's, all expenses paid, for five days through the most beautiful roads in America, Don? No agenda, no direction, and no place we have to be."

The Offer I was not Allowed to Refuse

"Naw, I gotta work, Buzz. But thanks for the offer!" I replied. "Work, work, work, it's all you ever think about. Get your ass down there, Don!" Wife-3 exclaimed in exasperation, "Do you realize what you just passed up?"

She ran the shop while I was gone. She even bought me a motorcycle jacket – with my money – made from some newfangled material that was warm, rain-resistant and had pads in the elbows in case I fell off a bike. I felt weird in it since I had worn a cheap black leather jacket my whole life that was too hot in summer, too cold in cooler weather, and loved to soak up the rain.

The Fantasy Crew

Lee Love – yeah, that is his real name – also had to be pried away from his business by his wife. At the time, Lee was the Webmaster for *American Iron Magazine* and an avid Harley rider from Virginia. He was very innovative in interweaving Harley-related news with the industry and general motorcycle news on the Internet.

Mark Zimmerman, the human encyclopedia on motorcycling, at the time was a familiar and popular tech writer for Buzz Kanter's magazines. He told me flat out in his low, monotone voice that he really did not care for Harley's because of their low tech, high price and the attitude of some riders. I did not have a problem with his feelings since they are accurate. If you can convert this kind of person then you have done something.

Steve Jurzak, the assistant editor of *American Iron* had a racing background. He ably demonstrated his riding skills around tortuous, scenic mountain roads.

Editor Chris Maida, the human eating machine, ate his own weight in food during the trip without putting on a pound, quite unlike the rest of us. Can you imagine huge pancakes that you cannot see for piles of whipped cream sprinkled with pecans for breakfast? And to this you add maple syrup! Americans and their eating establishments' sure can figure out a high calorie diet.

Buzz rounded out the crew. He scared the hell out of me while riding through Richmond, Virginia. I thought he had a bee down his pants the way he was bouncing around on the seat of the Fathead Bagger test bike. Turns out he was doing the jive while grooving to James Brown on the Tune Machine's much-improved 40-watt radio.

We all met at Harley's plant in York, Pennsylvania, to pick up the six 1999 bikes that we would alternate riding. Complementing three Fatheads, a Road King, an Electra Glide Classic, and a Dyna Lowrider were an Evo Softail Standard, a new FXSTB Night Train, and a 1200 Sportster Custom.

The York Factory has Five Main Functions

Ron Alexander, a supervisor of quality control, extremely knowledgeable and experienced about Harley-Davidson, met us at Gate 2 in a golf cart to take us to our bikes.

"Want to have a look around?" he asked.

Does a Canadian pee in the woods? Of course we did. Ron took us on a behind the scenes tour including places excluded to the public for safety or security reasons. The main areas are:

1. The first is manufacturing, such as making frames and sheet metal parts like gas tanks and floorboards. Items like front fork crowns and Springer front ends are machined, chromed, and assembled.
2. Man, I have to tell you what a treat it is to see a couple of hundred neatly hung, shiny black frames glistening out back in the sun. The only better Factory view is a hundred brand-new motors stacked up in the Milwaukee Pilgrim Road plant.

Paint is the plant's second function. The state-of-the-art Paint '91 building built in 1991 produces painted parts of ever-improving quality. This new structure is sandwiched between the archaic frame buildings.

3. Assembly is the third function. Assembly of all the Big Twins occurs here. Sportster production has shifted to a new plant in Kansas City.
4. Auditing finished bikes is the fourth. Up to four bikes a day are pulled at random from the line. Cosmetic inspections for chrome and paint defects are also performed. Tolerance inspectors check for things like wheel trueness. Bikes with audit results are displayed in the assembly plant for workers to see so they will be inspired to improve production.

5. Testing, Factory riders test each bike for about twenty-five miles on their own track out back with lots of curves and hills and stuff to expose any handling problems or mechanical defects such as oil leaks. Special tools like inclinometers are used on the bike to indicate wandering or off- tracking in order to make sure everything meets high standards. The assembly lines are sometimes interrupted midstream to make changes.
6. Before I forget, the sixth function of York is to produce military rockets for drones.
7. This is phasing out in order to allow more room for steadily increasing motorcycle production. Bombshell manufacturing is ceasing after many years as a stable income source.

Moreover, let me tell you about the workers. They have Harley oil in their veins. A lot of them ride to work, and they very much look the part. They are very proud. This here is Harley country.

Harley VP Kenny Sutton, the person responsible for bringing Milwaukee's Pilgrim Road and Capitol Drive motor and transmission plants into the modern world, would have a ball revamping the York facility. Harley-Davidson is working hard and effectively to enter the 21st century. York is on the list of things to do. Don't get me wrong. The facility is charming, interesting, and reeks history, but it is time for an upgrade.

Subjecting H-D Parts to the Elements

Oh, yeah, a caged compound we saw at the side of the audit area attracted our attention. Painted gas tanks, wheels, and assorted other parts were left out in the elements to gauge the effects of the sun and the elements. Some had been there for years. They also soak bikes in a salt solution, and then sit them outside to see how they fare over time. This kind of thing impressed me to no end. You can tell H-D is working hard at improving the product.

Lacing Spoke Wheels at York

One last thing, for any that have tried to true a laced wheel, it will already be apparent what skills are essential for that frustrating job. York has an automatic truing machine near the assembly line surrounded by mostly big, motherly black females lacing them with a dexterity I have never acquired in twenty-five years. No male chauvinism when it comes to the shop floor. I observed the same thing in Milwaukee where I saw women who were obviously working maternal homemakers assembling five-speed transmissions as easily as buttering bread.

Gettysburg

We rode away from the audit area on our test bikes to Gate 1 for security clearance and then onto the open road. It was sunny out so I chose the Evolution FXST Softail, saving the two models with windshields for a rainy day. My scheming backfired the next morning when I chose the Sportster.

We rode past Gettysburg, which is very close to the York facility, through the northwest corners of Maryland and West Virginia before we settled down in Winchester, Virginia. Gettysburg is a necessary go-see even if you are not interested in the Civil War. If you do not believe in ghosts, you may become converted. What an interesting and historically rich place!

Riding in Hard Rain

I woke up early to weather reports advising no rain and 80-degree temperatures. I, the master thinker, climbed aboard the 1200 Sportster since a windshield was unnecessary; we would be riding the mountainous Skyline Trail through Shenandoah National Park.

We went for breakfast in a pancake joint where Buzz inquired whether this 'ole Canadian boy ever ate grits. "No, man, I've eaten deep-fried Cod tongue and seal flipper and ostrich meat but never grits. I'd love to try them," I replied as I watched the tattooed server screw up her face in total disdain.

"Don't," she said.

"Bring'em on," I replied.

"You can have them for free. They're lousy," said she. They tasted okay to me.

We climbed on our respective bikes, Lee, Steve, and me with our cool-looking half helmets while Mark, Buzz, and Chris put on those awful un-Harley styles full-face ones with visors.

Well, was I not just the dumb cluck! It poured rain so bad that even my well-protected passport got soaked making all the stamps run together. Have you ever tried to go through customs-immigration at the border with a passport like that when you are a biker? Oh, yeah, its conspiracy time, what with them all trying to figure out where you been and what you are hiding. The last thing they believe is your story about riding through the rain, especially when the weather report said sunny skies.

The full-face helmet riders set a fast pace. Obviously, the rain did not feel like needles on their faces, and they could see. Oh, well, better a warm rain than a cold one. I mentally thanked Wife 3 for the new coat as my black leather jacket would have not fared well at all.

It will probably be a searing hot day, going through rush hour when I get my turn on the Twin Cam Road King with its heat-dissipating motor and big windshield. It is funny how things work out.

God's Country

We rode into Shenandoah National Park and onto the Skyline Trail. The lush scenery made me forget the rain as we went up and down and all around, stopping occasionally to look at the fogged-in valleys below.

Around lunchtime…I normally say *noon*…but on this trip, chronicling the time of day was by Chris's growling stomach and the need to eat, we switched bikes. The idea was for everyone to spend at least half a day riding each model in order to get a feel for the '99 lineup. I will take this tough job any time!

Yep, I got the Tune Machine FLHT; complete with faring and windshield the second half of the day right after the rain stopped and a nice warm sun came out. I turned up the radio and started to groove on the corners. Soon we finished the Skyline Trail and entered the Blue Ridge, considered one of America's finest touring roads.

Donny's Blasts from the Past: Sleeping in a Hobo Camp

I learned a long time ago to get a room for the night early in mountainous areas or else there would be no room. Yeah, I was crossing Rogers Pass in the Canadian Rockies a few years ago unable to find a room. The lone gas station's attendant told me to move on before he called the cops. I wound up in a hobo camp freezing all night with a grizzly bear rustling around in the forest just after dark. At least that is what the resident hobo said. It is hard to sleep clutching the knife that you just know is not going to help that much if the bear takes an interest in you.

No wonder I was cold as the morning sunlight revealed a glacier fifty yards away.

Nighttime, Cigars, and Young Ladies

So here we were, looking for a room in small towns just off the Blue Ridge. We turned up empty in town after town. Three hours later, a helpful gas station attendant found us rooms in Lexington, Virginia; buried here are Robert E. Lee and his horse.

Finding the rooms was another matter. Round and round we went. On a pleasant dark downtown street, we stopped and asked directions from a group of about six friendly girls who were dressed for a Friday night out. The pubescent teens giggled and were obviously infatuated with the symbolism evoked by six chugging Harley-Davidson's.

"Wait a minute," I blurted out in shock to the girl in the black vinyl miniskirt, forgetting all about decorum and directions. "What are you girls all doing with unlit cigars?" This was one week after the release of the Starr Report, and America was abuzz about its president's sexual conduct, which at one point involved a cigar. The girls all blushed, giggling nervously at each other while we blushed in tandem. It was time for the Over the Hill Gang to split. "Come on, guys," implored poor young Steve, the assistant editor. "I am not over the hill. I am just beginning the climb."

Next morning, as we entered a pancake house for breakfast we wondered who was waving at us from the corner. It blew Buzz away. Buzz lives in Connecticut. We were in Virginia. His brother, who lives in Georgia, was in the same restaurant with his family. We came upon each other purely by chance. On the other hand, was it by chance since Chris's stomach dictated the stop? After socializing with them and taking his young nephew for a ride on the Tune Machine, we set out for the Blue Ridge Trail again.

Busted

The morning ride was very pleasant on the Softail Night Train Mark had delegated to me. Mark had nothing good to say about his stint on this bike, and I trusted his judgment.

We stopped for lunch in a quaint, rustic mountain service center. It was my turn to ride the Dyna FXDL. Mark was reluctant to give it up as he was falling in love with the Lowrider. Mark loves function over form. The Twin Cam Dyna was functional while the Evolution Softail Night Train catered to form, its primary purpose being to look cool and evoke images of sleekness and toughness.

After feeding Chris, we hot-dogged around the curves that had speed limits ranging from 25 mph to 35 mph. We inadvertently assumed these speeds were indicators for elderly tourists in cumbersome motor homes. Wrong! Buzz was up front. He jammed on the brakes as two fawns wandered out onto the highway with adult deer at the shoulder about to follow suit. We all slowed down considerably.

A minute later, a Ranger with his siren screaming passed us as if we were standing still and ordered us to pull over. He chastised us severely for speeding but did not give us tickets. He told us that he was radioing ahead for a hundred miles for all the other Rangers to monitor our speed. We still had to test the bikes. We needed to get on faster roads where we would not have any more problems so we headed east.

Solving the World's Problems

Virginia is a great state for riding. We cooked along for the rest of the day until we wound up in the town of Tappahannock. Our motel did not have a bar nor was there one within walking distance so Chris, Mark, and I wandered over to a gas station and bought some six packs. We pulled some chairs out of our rooms and settled down to a few brew in the parking lot. We sat amongst the bikes under a clear star-studded sky.

This was better than any bar.

Out came Steve with a few more six packs, and he joined us with Buzz and Lee. Boy, the beer went down good after a hard day of riding. It is amazing how smart you get after a few beers. Everything becomes as clear as we solved problem after problem with great intelligence and wit. If only the others would let you speak.

Next morning, it was very easy to get your turn at talking. It did not seem that any intelligent thoughts come to the fore nor was there clarity of the mind.

Now that we were away from the mountains, the weather was getting very hot. When it gets very hot, I know I am getting a windshield. Sure enough, it was my turn for the Road King.

The Crab House

We rode through Richmond, the capitol of Virginia. Chris was hungry again. Up until now, he was not fussy about what he ate, but this time it was different. He had a hankering for crab since we were so close to the ocean, and crab it was going to be. Buzz knew a spot in Annapolis, Maryland. It took awhile to get our bearings, but we found Chris's dream on the Inland Waterway. It took him three hours to finish lunch in the "all you can eat" crab house with constant servings of more crab. He was one happy biker. Everyone ate so much that breaks were required to carry away the small mountains of depleted crab shells that began to interfere with the eating frenzy.

Now we had to book it for York since we were due back the next morning. We tried to make it to Gettysburg for a tour since my interest built up daily as my American friends educated this Canadian boy about the Civil War. I didn't tell them that I already knew quite a bit about the formal history, but it is fascinating to see the actual historical sites and listen to the tales passed down by soldiers about such events as musket balls colliding in midair. No such luck, as we did not get near York until well after dark. It is always good to leave something undiscovered while traveling though. It always gives you a reason to come back.

I come from a big city, Toronto, and am used to people being uptight and sometimes impolite, so I have to say something about all the people we met on this trip. Friendly, outgoing, and courteous was the overriding theme. This made our bike trip very pleasurable and memorable. However, I desperately needed a dieting vacation after too much fun during the Fantasy Ride on six new 1999 Harley's along some of the most beautiful roads in America.

Preamble to Evaluations

I liked all six bikes. Although it may seem that I am critical, it is important to note that Harley is maintaining engine styling in the face of increasing emissions control dictates.

Good for them since style is everything to the Harley rider. This will render many complaints superfluous.

FXST Evo Softail Standard Evaluation

The motor on this model had a new-to H-D sandblasted texture on the timing cover and the primaries. I wanted to see the effect of oil on these pieces. Eventually the breather will puke oil out and embed itself into the texture of these parts, ditto with accumulative road grime. I kept waiting, but it did not happen. When clean the parts look nice, but I am nervous about what they would look like over time. There is a reason the Factory black wrinkles or wrinkle-powdercoats parts. It is a great way to hide dirt and defects.

I asked about this when we returned to York. The H-D rep told me this was a new clear powdercoating called Textured Silver and will not stain. Over time, this claim has proven accurate. Within a few years, I have become a big fan as it really does stay clean and stain resistant. The silver paint version works wonderfully on Knuck, Pan, Shovel, and XL engine casings as it does on aluminum Pan, Shovel heads as well as on alloy Evo Sportster and Evolution cylinders.

The Softail ran strong and shifted beautifully. It handled well on the twisting mountain roads when I thought it might suffer relative to the other bikes. It cannot compare with the 1200 Sportster or the Dyna but what Softail chassis can?

The buckhorn handlebars seemed a little too close together, but we later found out this was due to the practical financial necessity of fitting more bikes side by side in a tractor-trailer during shipping.

Detonation, also known as pinging or spark knock, was a problem for us while riding on very hot days, but this model compared favorably with the others tested.

FXSTB Evo Night Train Evaluation

I did not want to ride this model because I had been listening to Mark's ongoing diatribe against it. He did not like having his feet straight out with his arms in much the same position as he reached for the straight bars.

Mark felt insecure at speed on this Harley as he lacked confidence in the handling. The truth is that Softail handling is not as good as many other bikes because the design tries to approximate the rigid frame. It is not about handling but looking cool. I rode this baby for a few miles and overcame my negative feelings. It felt good to me. Of course, I have never ridden anything but Harley's.

Exposed to different technologies, the others could make comparisons. I am the first to admit that a non-Harley enthusiast can have great problems with the product until reaching an understanding about the purpose of the bike.

Mark raved about the Dyna since it approached the functionality that he expected from his personal bikes. The conflict is all about form over function. Mark is a function person whereas he Night Train is form. It is pure style.

I did not think it was a stock Harley because of the higher risers, flat bars, and the custom seat. Harley is copying the aftermarket in its styling concepts, demonstrating that the relationship is symbiotic. Harley is trying to build a stronger industry rather than being parasitic in nature.

It is easy to understand that practical riders with broad motorcycling experience do not like the ride of the Evo Night Train. They are not trying to look cool on an aesthetically pleasing bike that connotes sleekness and has an aura of toughness.

Evaluation of the FLHTC Twin Cam Electra Glide Classic

The upgraded 40-watt stereo is a pleasure to listen to after substandard earlier versions. A stereo is a welcome addition on long hauls across uninteresting continuous landscape. This is not the case on the Blue Ridge. The scenery and constantly undulating curves occupy the pleasure centers of the mind. I did not miss a stereo until the last day when we were in heavy traffic skirting Washington-Baltimore.

I thought this bike would be awkward following the more agile models ridden by my road partners, three of whom had road-racing experience. It kept up with little effort. This FLHTC's predecessor, the FLH, is called the King of the Highway. The FLHT series is keeping up the tradition.

Top speed on this particular Fathead model was 95 mph. I found this disappointing for 1450cc, but a little tweaking could easily coax out another 10 mph on the top end. Later that night, while half-asleep and looking for a motel, I almost fell over a couple of times while stopping and starting on dark, uneven pavement. This top heavy touring motorcycle is no bike to be tired on in awkward, slow-handling situations. Maybe the true cause is I subconsciously know it would only fall over onto the crash guards. This was my fault and not the FLHTC Electra Glide Classic.

Twin Cam Road King Evaluation

I have had this theory for a while about one reason the Road King is so popular. It is the name. Think about it. Road King denotes being on the best bike as in the King of the Road.

However, wouldn't the thinking person label the Ultra Classic FLHTCUI as the Road King? Of course, what is logical about Harley-Davidson or its riders?

I was looking forward to my turn on this beautiful bike. Maybe I was building it up in my mind too much. This could be why I was disappointed. We were also on flattop in increasingly congested traffic under a hot sun that was getting hotter by the hour. The top of the windshield split my vision in half and refracted images. I had either to sit higher or slouch lower than I normally do. It became very annoying. To be fair, if it were my bike to fool around on, this last problem would be easy to resolve, as well as any of the other glitches I noticed.

In addition, the fact that this particular Road King would only go 90 mph with a new 1450cc Fathead engine did not exactly turn my crank. Engine detonation, even at cruising speeds should not have been happening with the new ignition timing spark matrix map. It is possible that the carburetor settings were maladjusted to the lean AFR side.

My overall impression of this bike was poor perhaps because my expectations were high. One thing that stands out is that the Road King is a looker, having a commanding presence.

Sportster 1200C Custom Evaluation

At 220lbs, I have always felt scrunched up on center-peg Sportsters and with my height of 5' 11", it is amazing that this entry-level Harley would not allow me to put both feet flat on the ground. Conversely, I have encouraged new riders to try a Softail since the rider feels in control, sitting inside the bike, allowing ground foot contact as opposed to being on the top of the XL with its straight back frame members. Well, I have changed my mind somewhat since this Sporty feels lower even though it really is not. Maybe it's the forward controls. I just felt more at ease on this fast little baby.

Another Harley conundrum is why is the fastest Harley the entry-level one? Furthermore, why does some of the Big Twin crowd look down on the fastest Harley as a girl's bike? I wanted to ride the hot rod 1200S Sport with the single-fire ignition, dual- plugged heads with happening high-performance shocks and the triple-disc brakes, but I already knew I was going to love that bike. As of 1999, the 1200S has to be the all-time fastest production Harley.

My mama told me that I could not have everything I wanted in life, so I settled into the XL Custom, which goes very fast and hugged those corners easily. The only problem was spark detonation. For the technical aspects of this, see *The Problem: Detonation*, a little farther on in this chapter.

The bike shifted effortlessly. In fact, the shifting on all the models felt improved.

The chrome is superb. As a customizer, I have great affection for a quality deep- blue-tinged chromium finish.

The Dyna Twin Cam Lowrider Evaluation

What a superb motorcycle! I thought the Road King would be the primo model. No way Jose¢! The rigidity produced by the transmission butting up to the motor combined with new rubber mounts produces the best hot rod Harley since the demise of the FXR. Evolution Dynas from their inception in 1991 to 1998 are okay but do not compare well with their FXR predecessor. The 1999 Fathead engine combined with the aforementioned structural changes provides a superior transference of horsepower that blew away every other model we tested.

It is fast and agile. I should qualify the last statement in that it is comparatively true within the context of the Harley family of motorcycles. The Dyna easily reached 110 mph. Compare this to 90 mph for the Road King and 95 mph for the FLHT we tested. This is all about weight-to-power ratios. I will deal with this in great detail in Volume II: *Performancing the Twin Cam*, Chapter VIII: *Torque and Horsepower*, section *Power-to-Weight and Weight-to-Power Ratios.*

All three bikes have triple-disc brakes. The Dyna Lowrider's decreased weight allows the braking system to be perceptually much better than the others, which are acceptable for the weight they must deal with.

The Dyna's Fathead engine became extremely noisy over the five days. The resident mechanics, Mark, Chris, and I became increasingly concerned. Coincidentally, the weather also got progressively hotter and the traffic more congested over the same time-period.

The engineers at York told us not to worry. They had finally figured out the problem, and it was no cause for concern. Further testing by Chris bore this out. How it will fare over a hundred thousand miles is still an unanswered question. In 2010, I can look back and unequivocally say that it has fared well, indeed.

This criticism aside, the Dyna is the bike we preferred to ride.

The Problem: Detonation

Detonation is an uncontrolled ignition event separate from that ignited by the spark plug. This destroys what is supposed to be a controlled burn. Also known as *spark knock* or *ping*, detonation sounds like ball bearings bouncing off the cylinder walls. All six bikes had this to some degree, but the Sportster was the worst with, surprisingly, the Road King coming in a close second.

In fact, Mark Zimmerman, who is an accomplished mechanic with the majority of his experience in other brands, was apprehensive about riding the Sporty because he thought it might blow up. Many other brands would suffer grievous injury if subjected to this level of detonation, but Harley's seem to tolerate it more. This does not make it right, particularly on the Fathead Twin Cam models that we rode. They have a graduated 12 x 16 cell spark matrix map, single-fire ignition-control system that is supposed to compensate for this very problem. The dual-fire Evo models, including the Sporty, are more susceptible to pinging since they have an ignition curve that is more like a light switch regarding advance/retard ignition timing. Pinging is a problem with both motorcycle ignition systems. Therefore, here is what we did.

In case we received some bad gas, we started going to busy national-brand gas stations to ensure quality and freshness.

- At the time, Harley recommended using 87 and up octane. We used the highest pump octane, which varied between a 92 and 93 octane rating.
- We avoided gasoline containing alcohol, which the Factory also recommends doing.

All of this was to no avail. I am sure the unresolved problem would have been worse without our precautions. To be fair, a couple of the late September days were brutally hot but not as hot farther south in midsummer. However, we were riding responsibly with no abuse to the bikes whatsoever.

Evaluation of Detonation

This is not good. Harley-Davidson's determination...and as a traditionalist, I am all for this policy…is to keep the basic shape and overall design of the V-Twin engine. This means that all of the possible solutions are a design no-go zone. They cannot use overhead cams, thus eliminating the valve trains with their aesthetic pushrod covers. H-D must avoid going to multi-cylinders, and, of course, a water jacket and radiator become sacrilege. The problem is that the Factory and consumers refuse to adapt to ever-more-stringent emissions controls through major engineering changes like those just listed. This conservatism is going to make life difficult for our beloved dinosaurs.

Addressing the problem in different ways is necessary since none of us wants to resolve this by imposing elaborate Band-Aid solutions. Harley-Davidson has improved the combustion chamber design, introduced spark map single-fire ignition systems, developed fuel injection, and built in exhaust anti-reversion valves along with other measures to combat gas emissions and detonation problems. Harley is working hard and as efficiently as possible within self-imposed guidelines to combat the extra heat generated by lean-burn systems that reduce emissions out the tailpipe.

Today's gasoline is produced for liquid-cooled engines, so there is not much anyone can do about that. Engines with air-cooling cannot control internal temperatures consistently.

The oil in a Fathead is 15° F to 20° F or hotter than in an Evo. The piston cooling jets at the internal base of the cylinders squirt oil up into the undersides of the pistons. This cools the pistons about 50° F, which is obviously a good thing. Sixty percent extra finning on the new engine is supposed to dissipate this heat, and it *does* try hard, as any Fathead rider can attest to while sitting in traffic on a hot day.

I think Harley has been remiss on one front. The beauty of Mark Zimmerman's broad knowledge base relative to my specific one, hit home when he said that he did not understand why Harley hadn't put oil cooler on the Fathead. He explained that this piston oil-jet technique is common with other brands. They all use coolers to reduce the increased oil temperatures.

Back at York, we discussed this issue with an engineer. Looking perturbed, he said that putting a cooler on would certainly address the higher oil temperatures, although *they were in a safe range* without the addition. When pressed as to why the Factory had not included this obvious step on all bikes, he replied that the powers that be felt the riding public would misinterpret this step as the Factory attempting to cover up a problem. I understand that riders can be suspicious; some to the point of paranoia, but the logic of that comment escaped me. Realizing he may have stepped out-of-bounds with his comments the engineer asked us for confidentiality.

It is not a big deal because H-D marketing skills and people like me explaining the virtues of oil cooling would assuage any public concern. I agree with his assessment that the engine could handle the increased temperatures but big multi-row oil cooler like the Jagg 10-row would relieve some heat rejection (dissipation) from the engine onto the rider's legs. It would also alleviate detonation by lowering cylinder head temperature.

I am currently installing 10-row Jagg oil cooler on my personal 1999 Twin Cam Road Glide FLTR and a 6-row cooler one on my 1954 Pan Chopper just on general principles. A cooler engine equals less detonation. It is not a cure but definitely help. Volume II: *Performancing the Twin Cam* will have a full chapter on oil coolers, how they work, which are the best ones and why plus what you the rider need for your personal ride; stock or performanced.

The next area that needs addressing is the spark matrix map. Now, we did not fool with the bikes Harley provided because we do not touch other people's property without permission. On my own personal Fathead, we have been fooling around plenty to reduce the ping. Adjusting timing retard with an ignition modifier and up jetting the carburetor in particular has helped but not eliminated the knock. Of course, it may not meet EPA guidelines anymore with these changes. Harley-Davidson is in a difficult situation with this emissions thing.

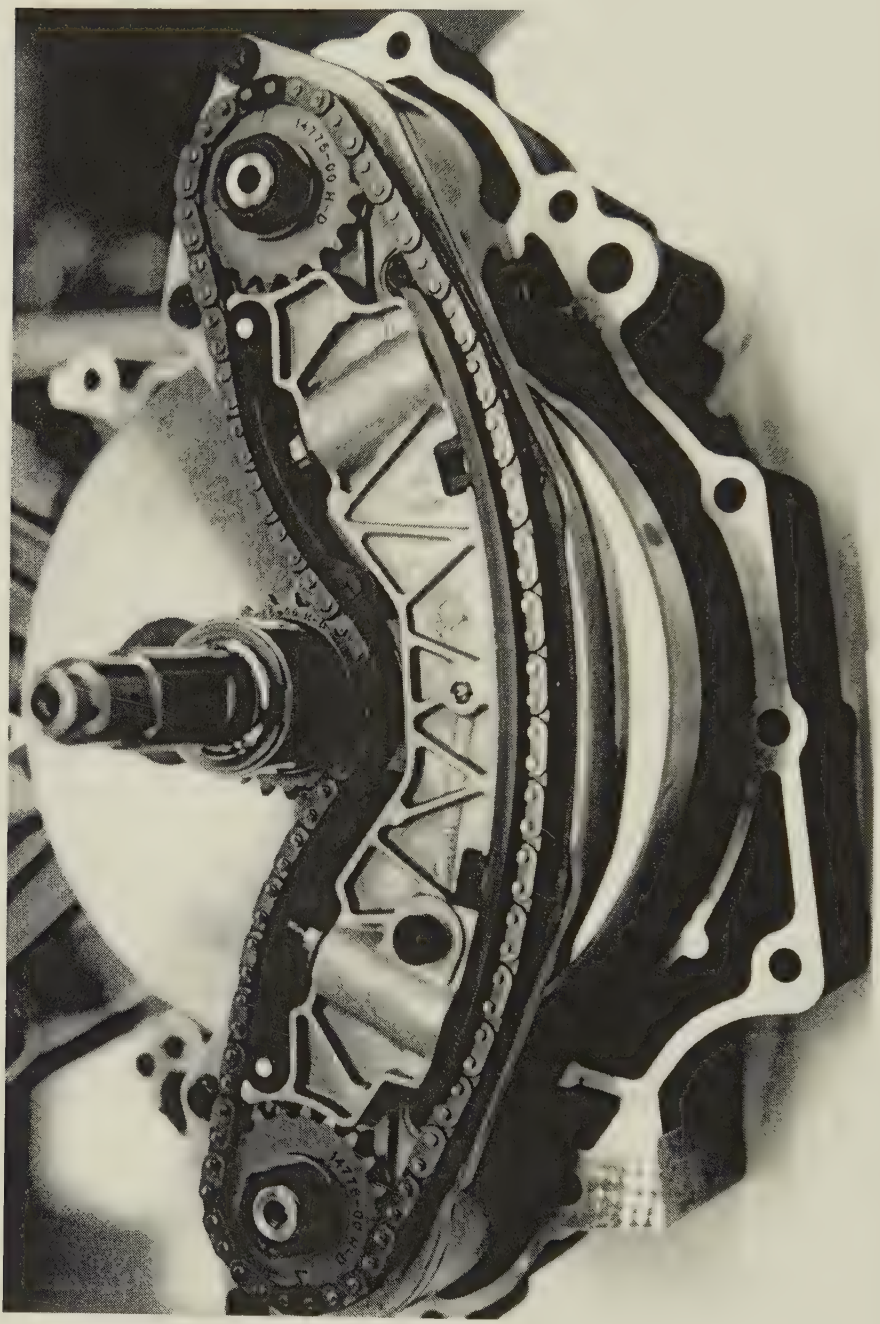
It is the first year that Harley has gone to the spark matrix ignition-timing map, and it is a huge improvement, but it needs some tweaking. I have full confidence that the dedicated workers at the Factory are tweaking away. Unfortunately, tweaking will fail to satisfy the EPA, ten or fifteen years down the road. Please see Volume II: *Performancing the Twin Cam*, Chapter IX: *Fuel Delivery*, sections;

1. Ignitions Coordinating with Carburetion,
2. Intelligent Spark Technology,
3. The Engine Management System,
4. Advance, Retard Ignition Timing,
5. Performance EFI Ignition and Fuel Modifiers,
6. Modifying the Electronic Control Module,
7. EFI Chips, Downloads, Burns,
8. Piggyback EFI Modifiers,
9. Output EFI Controllers,
10. Engine Management Software,
11. Power Commander,
12. Screamin' Eagle Race Tuner and Direct Link,
13. EFI Modifier Technology Changes Fast,
14. Changing EFI Fuel Delivery without a Modifier.

I realize the above may be intimidating but it is really not as I will dissect each topic in an easy to understand comprehensive way.

Finally, upon reflection I think two other factors increased unnecessary detonation on our test bikes:

1. They were all new and not broken-in yet. As parts mate together in the break-in process friction and resultant extra heat will occur.
2. I find this incomprehensible but I don't think that at least some of the bikes were optimally tuned for our evaluation.



Twin Cam Softail Counterbalancer Assembly

Pictured is a Softail counterbalancer assembly shown after removal of the right engine casing. Softail engine counterbalancers will wreak vibratory havoc if out of time with each other. This usually occurs with mechanic error. Bearing failure can precipitate an out-of-time situation but is an extreme case; always replace all four bearings whenever disassembling the engine. There are two bearings front and rear for a total of four. Two bearings (H-D 8989) locate fore and aft on the balancer's inboard side in the crankcase. The outboard balancer bearings (H-D 8991) also locate fore and aft in their outboard balancer housing (14716-00 fore, 14717-00 aft). The only other way for an out-of-time situation to occur is extreme wear. This may include the hydraulic adjusters (14764-00) collapsing; excessive sprocket and chain link wear or the chain losing a roller bushing(s). The chain would have to jump a sprocket tooth or teeth to bring the assembly out of time. Always replace chain and sprockets as a set (14762-00) during a bottom end rebuild. This is especially important with the mating parts, as there is much labor involved to get to them if requiring service. Chains are demonstrative in their wear capabilities of mating parts. Sprocket teeth wear in the opposite direction of chain rotation. First, the teeth will narrow down from the top narrowest portion of the tooth. The narrowed top will then start to wear directionally as if pulled backwards. This hooking will increase until the tip breaks right off. The chain will begin cutting a new tooth, albeit a shorter one and the process will start all over again. This will continue until the chain will start skipping over the progressively diminutive teeth. The same will be happening to the other sprocket(s). The workshop manual says to replace sprockets if they show severe hooking. It is just too hard to get at them to allow any wear without replacement. At this point, the chain will also be badly in need of replacement, as it will be stretched very unevenly, rollers will be damaged, kinking may occur until a link finally breaks, snapping the chain. We do not want any of the above to begin happening in an enclosed engine casing as Armageddon will ensue. Always inspect the chain for missing roller bushings, side plates, and adverse wear from turning, which may include burn marks. Once again, my credo is to replace, replace, replace when a wearing part is deep inside an engine or transmission. There is a sprocket at each counterbalancer end and the third is a center sprocket on the flywheel pinion shaft. There is a procedure for checking alignment of the flywheel pinion-shaft center sprocket to the balance-shaft. The balance shaft sprocket alignment tool (HD-44064) slides over the pinion shaft up against the center sprocket face sometimes called the timing chain gear. The alignment tool's appendage can now swing over the front and rear counterbalancer sprocket-face for alignment measurement purposes. Alignment must be within .014" (.356mm). Adjust the alignment if beyond specifications by replacing the spacer behind to offending sprocket with a correct dimension one. The nine spacers vary between .130" (14780-00) thick and .210" (14788-00) in .010" increments.

Twin Cam Softail Counterbalancer Assembly

The Factory's addition of placement indicators, timing marks and color-coding achieves a simplified methodology for timing the counterbalancers and chain. First, the following timing marks on the sprockets and timing link colors on the counterbalancer chain must face outwards. Front and rear sprockets are stamped F and R for correct placement within the chain. With installation, always use new sprocket nuts (H-D 7974) and washers (H-D 6852). With the F and R stampings at the 12-o'clock position within the chain, a timing mark will be at the 3-o'clock position on the front F sprocket, while a similar timing mark will be at the 9-o'clock position on the rear R sprocket. The center-sprocket-timing-mark should be at the 6-o'clock position on the pinion shaft. This involves rotating the flywheel assembly so that the sprocket presses on with its timing mark directly below the crankpin oil-feed hole in the pinion shaft. There are three colored chain links for timing purposes. The middle colored link in the chain must seat directly below the center-sprocket timing mark. The fore and aft colored links will now align with their mating sprocket timing marks. Counterbalancer shaft housings are marked F and R for correct placement in the front or rear engine-casing compartments. The balance shafts may be used front or rear but install with the smooth side down. Always return a used balance shaft to its original front or rear positioning. However, if purchased as a kit, with a sprocket, the balance shaft kits will fit either front (14789-00) or rear (14790-00). Now, insert the retention pins for the balance shafts (HD-44062), inside the supports, fore and aft thereby locking the balance shafts in time with the engine. The center of the otherwise round pinion shaft flat for oil pump alignment is directly above the center-sprocket timing mark and below the crank oil-feed hole. It is essential that the retention/retaining pin in the end of the shaft do not become loose or dislodged. Consult the manual to perform a hydraulic tensioner leak-down test. There are two hydraulic tensioners, one before, and the other aft of the center sprocket. The tensioner comprises of three parts; a small cylindrical hardened steel piston, a tensioning spring, and a plastic vent cap. The hydraulic tensioner spring keeps the piston up holding the counterbalancer chain taut while at rest. Then check spring free length. It must be at least two 2.00" (50.80mm). The tensioner guides must not have any grooves or markings deeper than .090" (2.290mm).

The Year 2000 Harley-Davidson Twin Cam 88B

This engine is a bulletproof platform for the future relative to what has gone on in the past. Five and a half years in the making, this TC88B was designed with durability and reliability in mind. The engineers are expecting a minimum 100,000 miles (160,000km), before rebuild.

In fact there are parts in both the 1999/2000 Twin Cam 88A (Alpha) and its vibration counterbalanced equivalent, the 2000 Twin Cam 88B (Beta) that will not need replacing for a couple of hundred thousand miles, for example the bottom-end pinion shaft bearing (24604-00) that rivals those used in top-fuel dragsters. Many components of this engine are over engineered. It, along with the TC88A is the most superlative effort in engine design that I have ever seen or hoped to have seen in my thirty years of working on the American V-Twin. If your heart desires this staging area for more power, it will be available, dependable, fast, and resilient.

What are the differences between these two Twin Cam 88 engines, and what applications are they used for?

1. First, there are upgrades to strengthen some key parts in the bottom-end timing chest area from 1999-early 2000 models.
2. However, the main change is in the Twin Cam 88B bottom-end used in the rigid-mounted Big Twins like the Softail.
3. The TC88B has counter-rotating balancers fore (14789-00), and aft (14790-00), attaching to the bottom- end flywheel assembly on the right side.

The rotating balancers are heavy. They are comprised of the balancers, fore and aft, balancer supports (14716-00 front, 14717-00 rear), and a chain drive kit (14762-00), consisting of a front, center, and rear chain sprockets with a long chain that connects the fore and aft balancers at opposite ends of the engine on the right side. There are bearings that the balancers ride on. The H-D part number for the rear ones farthest inside the balancer appendages of the engine case is HD-8989. The part number for the front bearings is HD-8991.

The balancing chain does not travel straight in the shortest line from the front sprocket to the other rear sprocket as it takes a bit of a dip in the center to interact with the drive sprocket that powers the balancers. The drive sprocket is necessarily lower as it locates on the pinion shaft close to the right hand flywheel.

1. The appearance of the bottom part of the engine is changed. There are front and back protrusions or bulges to accommodate the twin balancing mechanisms.
2. The location of the front balance shaft necessitated radically changing the traditional Harley front motor mount used forever.
3. The Beta 88B engine used in the Softail models weighs 14lbs more than the Alpha TC88 powering the FLHT and Dyna models.
4. Harley engineers say that this balancing system is maintenance-free for the life of the engine. That is a confident claim but most everything else H-D has done is impressive to a critical person like me.
5. However, the industry is having a hard time buying and supporting this claim. I, too, have nagging doubts emanating from the pit of my stomach. I will step into the future in a bit to see what actually transpired over time but first let's look at the system itself.
6. A chain (14762-00), located between the right flywheel and the right engine inside case, connects the two balance shaft kits to each other.
7. The right-hand-side engine-pinion shaft powers the chain drive sprocket.
8. The timing chest itself has been moved out somewhat to accommodate the chain drive system.

9. There is some room between the inside timing chest engine casing that separates the timing compartment from the bottom-end crank (flywheel assembly), compartment on the Alpha Twin Cam 88. This extra room is actually between the compartment engine case and the oil pump sitting on the pinion shaft but bolted to the cam support plate.

I am getting ahead of myself, but this space in the Twin Cam 88A is where we will locate the aftermarket S&S Reed Valve to control oil blowby to the outside world in years to come. It restricts air from traveling both ways coming through the pinion bearing as the descending pistons force air out of their way and the ascending pistons suck air back through the bearing.. I will be dealing with this initially complex, but really, pretty simple subject of blowby in detail later on. This future fix will not be suitable for the TC88B engines. The balancing chain, its drive sprocket on the pinion shaft, and the chain support assembly (14728-00) that includes the hydraulic tensioners to tension the chain have taken up the extra room found on the TC88A engines.

1. The TC88B balancing assembly is on the inside of the bottom-end compartment casing beside the right-hand pinion flywheel component of the crank. The TC88A extra room (space) is on the outside of this compartment casing on the engine's timing chest side.
2. H-D eliminated this extra space between the compartment wall and the oil pump by moving the inner casing wall out on the Beta engine to give space for and to accommodate the balancing chain system.
3. The corresponding balance shaft sprockets and chain are timed via easy-to-see timing alignment marks to eliminate vibration. Incorrectly timing these will reintroduce engine vibration big time.
4. The shape of the heavy balancers themselves is like an elongated half circle and ride on end bearings. The half circles, if out of time with each other will produce
5. vibration not cancel it.
6. Two hydraulic chain tensioners (14764-00), to the front and rear of the pinion engine shaft located in the chain guide bracket (14728-00), ensure an always properly adjusted chain.
7. Oil is filtered a second time internally before feeding these tensioners.
8. I will pick up the oil flow after it exits the oil pump and enters the cam support plate that guides the oil to its various destinations like the top end, the bottom end, and, of course, the TC88B balancer chain guide bracket and its hydraulic tensioners.
9. Oil feeds down the center passage of the support plate and then enters a passage towards the rear of the cam support plate.
10. This oil exits the inboard (inside or inward), side of the plate and enters a hollow dowel in the crankcase. This hole seals with a very necessary O-ring (H-D 11301).
11. Inside the hole sits the chain guide oil-filtering screen (24983-00).
12. After the feed oil passes through the fine mesh filter through the engine case dowel, it travels through a passage in the right-hand crank casing and feeds into the chain guide where the oil transfers to both the front and rear hydraulic tensioners. Any air trapped in the tensioner hydraulic body vents out into the flywheel (crank) compartment.

For those of you familiar with a Shovelhead tappet block screen, this looks the same. It has a round opening at one end where the oil enters. There is a round fine screen approximately one inch long attached that is pinched off at the far end. This screen blocks any debris that might enter the chain guide bracket. Obviously, cleaning the screen and replacing the O-ring every time the engine is disassembled is necessary since the screen has no regular maintenance schedule.

I am very uncomfortable with this lack of maintenance schedule. Intellectually, I know that the oil filters via a synthetic media 10-micron oil filter (5-microns in 2006 to present) that filters out a high percentage of particles bigger than ten-millionths of a meter. I also know that the chain-guide-screen-filter will sometimes let particulate through that are bigger than 10-microns. It is unfortunate that the location of the filter is difficult to access without disassembly of the timing chest components.

What makes me nervous is what might happen, if over time debris blocks this fine mesh filter. The hydraulic counterbalancer chain tensioners will not be able to work without oil. At least the warning to turn off the engine before further damage ensues will be extremely loud and impossible to ignore. Collapsed hydraulic lifters allow parts to really pound away. My concerns turned out to be unwarranted. As of 2011 there have been no real problems with this filtering system, which is an indication of its superiority over what has gone before in previous engines.

In year 2000, there was tremendous speculation about how reliable this system would be. The rumor mill was churning with stories of blowing chains, heavy balancers going berserk inside the engine and so forth. Performance people (in 2000) are saying to stay away from increasing horsepower on the B engines. If I skip a few years ahead, I must say that these rumors also proved to be unfounded and much of the speculation groundless. Mainstream performancing has not demonstrated problems. As I have said, I have yet to hear a collapsed hydraulic balancer chain noise indicating a plugged filter. If I go to 2007, H-D begins using the same type of hydraulic tensioners used to tension the long counterbalancer chain to replace the problem-plagued spring-loaded timing chain tensioners'. Looking back in retrospect from 2010, I will say that the complete counterbalancer assembly will last at least as long as the top end before a rebuild.

The external rubber isolation system on the FLHT and Dyna models absorbs most engine vibration, which makes the counterbalancing feature unnecessary with this methodology. Rubber mounting and counterbalancing are two different ways of accomplishing the same thing, lessening vibration for rider comfort.

The TC88A is faster than the TC88B

The rubbermount 1999 and 2000 TC88 models are a little faster than the counterbalanced rigid-mount TC88Bs. Why is this? The engine must use some internal power to drive the counter-rotating balancers, and this internally robs the engine of horsepower otherwise delivered to the rear wheel. The mechanical term *parasitic power loss* is descriptive. There is about a 3% parasitic power loss, about ½-horsepower. This trade-off is minimal as is the weight-to-power 14lb differential in engine weights when looking at the gain of a smoother engine.

Engineers claim a 50% reduction in vibration on the TC88B. It certainly feels at least that on the ones I have ridden. For the first time in thirty years, I can see out of the rearview mirrors at speed on the rigid-engine-mount models.

Above the barrel-base O-rings, everything is essentially the same in appearance.

TC88B Oil Pump Change

The 2000 Trochoid geroter oil pump (26035-99A) is similar to the 1999 version (26035-99), but there are enough minor changes to prevent them from being interchangeable. A skilled mechanic can do it, but the average person should use the recommended pump. This basic-style oil pump is extremely efficient; delivering both high pressure and high volume and its genre has been used on Sportster models since 1977.

In fact, the TC88 also begins use of the HD-26035-99A. Oil pumps for both engines upgrade further to HD-26035-99B but the pump revamps (26037-06) with the 2006 Dyna and all 2007-to-present models in part because of a new cam support plate and other welcome changes to the timing chest chain drive system.

Interpreting H-D Part Numbers

Harley part numbers always end with a hyphen followed by two digits that indicate the year of introduction for the particular part.

The exception to this is some bearings, nuts, bolts, and roll pins. Seals may have three numbers and bearings usually have four. O-rings, seals, or retaining rings may have five numbers. These three-, four-, and five-numbered parts do not have hyphenated year numerals after them. Therefore, we cannot distinguish the year of first use with these parts.

A hyphenated part number ending with two digits indicating first date of use may carry the letters A, B, C, and sometimes even a D after them. This indicates a modification, upgrading, or change of the component to resolve some issue with the original part.

Oil Pump Upgrades

In the above oil pump discussion, we see that the 1999 oil pump (26035-99) was upgraded in year 2000 (26035-99A). It was also upgraded in 2003, indicated by the part number 26035-99B, which was used until the 2006 Dyna, when the changes were great enough to warrant a totally new part number (26037-06), which has continued use on through 2007-to-present Twin Cam TC96, TC103 and the CVO 110's.

The year 2000 oil pump changes were necessary, in part, to prevent gravity feed of the oil from the raised TC88B Softail oil tank into the engine when at rest. As you probably know, the rubbermount TC88 models have their oil reservoir below the oil pump underneath the transmission. Because the TC88B pump changes were also incorporated into the TC88A pumps in 2000, both engines use the upgraded parts. As a side benefit, they have a few more pounds pressure at idle. This is a result of tightening the pump up in an attempt to prevent gravity feed at rest.

Rear Cam Drive Sprocket Attachment Issue

The other major change from year 2000 TC88A and TC88B models from the 1999 TC88A models revolves around the drive sprocket that rotates the dual cams. The 1999 models had an integral key on the sprocket to prevent it from moving on the pinion shaft. This was an engine weak point. With hard, aggressive riding habits or high-performance modifications, the key could shear. Andrews Products makes a superior sprocket with a stronger separate keyway to use on the 1999 models. H-D changed this design away from a key slot to a multi spline fitment that effectively continues today.

TC88A and TC88B Engine Weight

The 88B engine weighs in at 179 lb and 165 lb for the 88A. Both are heavier than previous model Evolutions, which are around 155 lb. The excess weight over the Evos comes from beefier parts translating into superior quality. The Beta (B), engine weighs more that the TC88B because of the counter- balancers, right engine case redesign, and their support parts.

Teething Problems

The 1999 Twin Cam Alpha models experienced a series of teething problems. I will discuss them at length in the next chapter, Chapter II: *1999 to 2000 Teething Problems.* H-D engineers corrected some of these boondoggles before the advent of the TC88B but many carried over into them also.

[1] Rosenblum, Dr. Martin. November 1998. Letters to the Editor. Published with permission of *American Iron Magazine*® www.Aimag.com. Issue 111, page 14.

[2] Metz, Skip. Discussion in March 1998 with Buzz Kanter, Chris Maida and myself. Harley-Davidson Archives, 3700 West Juneau Ave, Milwaukee, Wisconsin, USA.

[3] Sutton, Kenny, VP and GM of Harley-Davidson's powertrain operations and Jerry Wilkie, VP, Harley-Davidson and Buell President. Discussion in March 1998 with Buzz Kanter, Chris Maida, and myself during tour of Harley-Davidson Capitol Road and Pilgrim Road facilities.

[4] Harley-Davidson. *Harley-Davidson Service manual FLT Models* Part No. 99483-99. Engine, Specifications, Flywheels, page 3-3.

[5] Ibid. Page 3-3

[6] Harley-Davidson. *FLHTCUSE^3 Model 2008 Harley-Davidson Service Manual Supplement* Part No. 99500-08. Engine, Specifications, Flywheels, page 3-2.

CHAPTER II

1999 to 2000 Teething Problems

Donny, What Went Wrong?

I am disturbed. You wrote such glowing articles on the TC88 when at the Factory to learn about the new engine in 1998.

Why are there all these problems? Why are you *now* reporting about so many deficiencies in the new engine? I can tell you have a high level of integrity but this does not add up. What has happened?

Is this a great engine or is it a piece of crap?

I am going back to an Evo.

The above complaint is from a compilation of many letters and emails.

The Gist of My Answers

This has bothered me a great deal also.

1. What I saw at the Factory was wonderful. The new engine was and is a huge step forward for Harley-Davidson.
2. Computer design analysis should have caught the boondoggles.
3. The rapid upgrade in specialized equipment, especially robotics, is particularly impressive relative to the antiquated lathes and milling machines that used to dominate the Factory floor.
4. Harley's pride in its workers is evident every step of the way. The workers are enthusiasts and many ride the product, as they are proud Americans in a proud USA company.
5. Quality control is now an ongoing theme. Sealed rooms with light-measuring equipment ensure parts are to specification.
6. Cold-running of engines off the assembly line look for and shake down defects or out of tolerance components. From what I saw there are not many.
7. Computer generated test results dictate the percentage of parts and components coming off the line that go for further quality checks and testing.

In short, Harley-Davidson is making ongoing huge strides in improvement every day they open the doors. Look where they came from. Look where they are today and where they are going tomorrow. You will understand why I was and am still so impressed.

Mind you, they are still in the dark ages with respect to what technology is available. However, do you want that technology to change the look and feel of your Harley-Davidson?

These ongoing improvements will involve future changes like the elimination of carburetion for precise EFI fuel delivery. I am happy that this is forced change onto the Factory with ever-increasing EPA dictates. Even the Sportster will be fitted with electronic fuel injection (this in fact did occur on all 2007 models).

Of course, revamping or replacing the current 1995 to 2001 Magneti Marelli EFI with another manufactured system is necessary, as the system is too small, has the injectors facing the wrong way, and it sucks air, to name a few problems. Nevertheless, make no mistake, when Harley finally gets EFI right, your bike will be faster, use less gas, and produce fewer pollutants. Fiddling with and constantly adjusting fuel delivery will be outdated. The bike will also start easier. This will especially be noticeable in cold weather starts.

However, other technologies such as eliminating the valve train, which includes the visible and beautiful traditional chrome pushrod tunnels with overhead valve cams, will mean a further redesign of the top end. Of course, the timing chest will not need to be the same size or shape anymore. The bike would become more reliable, faster, and be able to rev like a Japanese bike, but do we want this? I think not.

A water jacket over the engine and radiator out front would produce consistent engine component temperatures with resultant efficiencies and reliability improvements not requiring the inefficient air-cooling anymore. We might as well throw all the tradition and history out the window. Me, I will stick with a cumbersome valve train and a sleek engine design and forgo all the stuff that will make a Harley better able to cope with the present and future. Although I am a high-tech person, I am like most of you who want a low-tech product because of the aura, the feeling, and the rumble that makes us all, feel so good.

You know, I feel like I am rationalizing. Everything I am saying is true but how did some of these problems occur? Surely, the test riding of some Twin Cams for 100,000 miles must have exposed them. In retrospect, I can only believe one of three things;

a) The test miles were grossly exaggerated.
b) The problems did manifest themselves but nothing was done about the ones that survived into production.
c) Bean counters authorized some cost saving initiatives last minute that inadvertently caused these problems.

If I had to guess, I would say that:

a) Prototype engines were built better than production ones. I believe the test mileages because I do not feel anyone deliberately lied to us about factual statements such as this plus the engine I saw all apart in the Archives had mucho miles on her. As a mechanic, it is easy to discern this.
b) Bean counters probably did institute cost saving measures that cost a lot more with inadvertent results like warranty problems.
c) Perhaps meeting modern emissions controls with old air-cooled technology leads inexorably to problematic situations.
d) Sometimes it is less costly to pay for warranty claims than to hold up production and do costly redesign procedures. I have no evidence of this but it is well known that some manufacturers make this cost-benefit analysis and follow the cheapest road. Did this occur in this instance? I have no idea but I will say that Harley-Davidson is a reputable company with its shareholders, management, and workers proud and enthusiastic of their product.

Comparing the TC88 to the Evolution Engine

I am going to examine the problems to date and explain why I think they happened. Then I will review Evolution engine problems just to put all of this into perspective. Evos are like "the good old days" where all remember the good times while the bad experiences fade away from memory.

The new TC88 engine compares extremely well with the Evo in the final analysis. That good old Evo that many riders idolize as bulletproof has had more than its share of serious problems. I will be analyzing this as we go on.

I am not making excuses for the Factory or myself. If it is my fault, I will castigate myself mercilessly. I sometimes wear rose-colored glasses when surrounded in Harley heaven.

I am sure there is some passive deception on the part of the manufacturer since they like any other company will present their good side. This is what marketing in a capitalistic society is all about.

I feel some problems evolve from mass production, where a tolerance variance is necessary that you will not find with prototype models. An example is noisy timing chains on some Twin Cams that are supposed to be quieter than antecedent timing gears.

a) Meeting emissions controls does create problems. The disintegrating rear cam support plate *ball* bearing in 1999 is such a case. Ball bearings are quieter than roller bearings but in this case a roller bearing is suited to the stresses imposed. Consequently many real cam ball bearings failed before acquiescing and substituting a roller bearing to resolve the mechanical problem.

b) Correcting many of these problems require some time; minor remedial changes in the next model year an example of which, is the keyed rear cam drive gear replacing with a multi-splined gear. More complicated engineering design changes may wait many years. Perhaps the cam timing chain apparatus redesign in the 2006 Dyna and all 2007 Twin Cams is a good example.

c) Major engineering blunders are the most serious as they should be preventable on the computer design model development table. Once in production changes of this magnitude are a big deal. Again, I think the 1999 to 2006 timing chest design is probably a good example.

d) A manufacturer will subcontract or vendor out some parts production to other companies. The vendor may make unintentional mistakes or take shortcuts unbeknownst to the primary manufacturer that causes problems. There are many examples of this. Can you blame H-D if the vendor supplies a defective CV carburetor float needle or diaphragm jet needle, or a part was not heat-treated sufficiently leading to failure? These are real instances that have actually occurred. If the reader takes the time as I have done to read through many of the safety recalls over the years (www-odi.nhsta.dot.gov/cars/problems/recalls/recallsearch.cfm), it will become readily apparent that many problems occur because of improper vendor supplied components. H-D sub-contracts to reputable companies like Kehein, a subsidiary of Honda Motor Company and Yuasa to name two so we are not talking about Hardly Dooright here in his back alley garage.

e) The bean counters trying to save expense will often create a problem that did not exist with the prototypes. Examples of this frugality gone wrong may be snapping cam gear bolts and shearing keyways that I will discuss a little later on.

f) Immediate, as in manufacturing immediate-time corrections will also occur when found out by quality control and dealer/consumer feedback complaints.

Some blame problems on mistakes or overlooking situations such as the loose fitment of the pinion shaft in the pinion bearing. Correcting and repairing these goofs occur as soon as they are isolated.

Lastly, some boondoggles are simple teething problems with a new product. In fairness to Harley-Davidson, it is instituting major upgrades in materials, design, and manufacturing technique at a breathtaking pace when viewed chronologically. However, make no mistake; H-D is going in the right direction both philosophically and in implementation.

Service Recalls

The manufacturer will deal with many teething problems immediately, especially if safety is a concern via a system of Service Recalls, whereby the company contacts affected owners by mail and through their dealer network. Some examples follow.

Fuel Tank Vent System & the Bank Angle Sensor

Harley-Davidson (Service Bulletin ML-370) advises about a defect with the bank angle sensor (32495-98) on some 1999 and 2000 FLT's. In addition, the bulletin discusses a gas tank-venting possible malfunction on some but not necessarily all, the same year and model carbureted bikes.[1] These two potential problems may possibly cause the bike to stall at speed. This, of course, becomes a safety issue if stalling occurs at an inopportune time.

Mailing a notice to all owners of affected bikes about this or other concerns as they may arise is a standard and responsible procedure by the Factory. Dealers also correct unsold motorcycles on the floor before selling them and will check incoming bikes for service to ensure any recalls have been performed. Most times the service, both for parts and labor, is free to the customer.

If affected by the problems in this particular service bulletin, the result will range from annoyance to the dangerous. I highly advise responding to these bulletins when issued by the Factory.

Bank Angle Sensor

The bank angle sensor more correctly is a switch that electrically signals the electronic control module (ICM, ECM, or ECU)), computer if the bike tips beyond a 55-degree angle.

This is actually a nifty item since in the past if your bike fell over the engine would keep running unless it stalled. If in gear, the bike would start to circle on its side if the rear wheel contacted the ground. Lots of damage has occurred in these situations. This has also caused many rider/passenger injuries as well as engine damage if the throttle stuck open.

The bank angle sensor feeds this information to the computer. The ECM will turn ignition and EFI fuel delivery off to protect you and the engine in the event of an accident.

If the Twin Cam, particularly 1999 and early 2000 models, starts coughing and sneezing for no apparent reason, sometimes just shutting down, the bank angle *switch bracket* may be the culprit.

This happened to me while at Daytona in 1999 while riding my 1999 carbureted FLTR Road Glide. It was frustrating because the symptoms mimicked a blocked vent. In fact a vent might have blocked in this situation also, which I will get to. It could have been electrical, but the symptoms felt like it was gas-related. I would be riding along in the warm sun when the bike would inexplicably start to cough and lose power. Sometimes it would perk up for awhile and sometimes it would quit. This became very annoying not to mention dangerous because of the unpredictability. The analytical mechanic in me soon eliminated a venting situation even though we will see later on that the vapor valve venting alignment problem often occurred in tandem with the bank angle switch malady.

Checking for shorts did not resolve the problem since there were none. It is easy to hate electronics when they are not working right, blaming them sometimes when it is human error or a malfunctioning inanimate support part.

My buddy Stormin' Norman cracked a beer and started poking around, not really knowing what he was doing. Sometimes you need someone just to stumble through a situation, especially looking at stuff an educated person knows *cannot* be the problem.

"Is this supposed to be loose?" he said.

"What the heck is that?" I replied. How would Stormin' know if I did not? I had broken one of my rules. Always do a visual inspection of the whole bike, looking for something untoward. Then do a touchy-feely inspection. Grab parts, wiggle them, and stuff to catch problems. They may look okay but are not affixed as designed.

I did not know what the part was since I had not seen one before, but I knew one thing; it was not supposed to flop around. I knew something else; it was electrical because of the attached wires.

- I pushed the part upright to where the wear marks indicated it should be and easily started the bike.
- I let it flop down and tried to fire my bike. It would not start.
- I found a plastic tie wrap and fastened this mystery part firmly in place. No more flopping allowed.

My FLT never gave me an abnormal problem again, well, except for a disintegrating outboard rear cam bearing, prematurely worn inboard cam journal bearings, and of course, the rapidly wearing timing chain tensioner pads. After repairing these problems with aftermarket parts, I never had a problem again with this otherwise excellent engine.

I looked for a shop in Daytona with current workshop manuals to understand further, what had gone wrong with my 1999 FLTR. I had fixed the problem without knowing what the trouble actually was. I could not find any manuals because the 1999 Twin Cam was so new. Back in Toronto, I put a special order in for the new manuals. It was easy to figure out from there on in.

The Factory had inadvertently put early TC88 bank angle sensors on a flimsy bracket (72334-96A) that can break from vibration. The sensor can then flop around, sometimes flirting with the 55-degree angle and sometimes crossing the line. The bike will shut off until the sensor flops in the opposite direction, allowing it to fire up again.

It is important to note that the sensor and computer are working fine. They are only reacting to the sensor going past 55-degrees. This problem should never have happened. Probably, the bracket was fine on the prototype Twin Cams, but penny-pinching by the bean counters saving costs in production was responsible for this malaise.

Vent System

I cannot remember running across a particular venting problem that the Factory is talking about in the above service recall. If I did, I have forgotten about it since venting problems have been going on forever, not only with Harley's but with all the other motorcycles as well.

It may well be that this problem occurred in tandem with my failing bank angle switch bracket and I unknowingly fixed it at the same time. Well, I would know. I just would not think about it. The vapor valve is in close proximity to the bank angle switch so securing it in place at the same time would be a no-brainer. In fact the vapor valve tipping could have produced the same result just not as fast.

For the experienced, venting blockages offer clear symptoms, are easy to diagnose, and normally very easy to fix.

The symptom of an overflowing carburetor, which I will discuss farther on, did not occur in my situation, so perhaps my vapor valve was just tilted off its necessary perpendicular positioning and did not fully flop over. The follow up Service Bulletin M-1093 to the above-mentioned ML-370, Safety Recall Code 0101 issued on November 19, 1999: *Vapor Valve/Bank Angle Switch Mounting* applies to some but not all 1999 and 2000 FLT Baggers manufactured before October 14, 1999.

Look at the fifth digit of the vehicle identification number (VIN), which indicates the family or type of Harley. This service bulletin refers to the letters *D* and *F*, which are the FLT's, FLHT's and the FLHR's, which Harleyese translates to the term *Baggers.*

The sixth letter of the VIN indicates which model of the particular family of Harley, in this case D or F, we are looking at. This includes every model; DD-FLHT; DG-FLHTC Shrine (Shiners special edition); DJ-FLHTC; FC-FLHTCUI; FD-FLHR; FF-FLHTCI; FG-FLHTCUI w/sidecar; FL-FLHTCUI Shrine; FP-FLTR; FR-FLHRCI and FS-FLTRI.

I mention both bulletins because the first one said only carbureted models are affected. The second includes all the FLT family models including the injected ones as we see from the above listing. I cannot really speculate about this difference except to say that the venting problem would affect carbureted models more severely than fuel-injected ones, as we will see.

Gasoline evaporates very easily into the air. A good fuel has this quality. It also makes it an environmental pollutant. Harley-Davidson's have had a vent hole in the gas cap forever. Older gas caps had a two-way venting system, which is just a hole monitored by ingenious valves whereby air could travel into the tank to fill space by the vacating gas. They also allowed evaporating fuel to vent out into the atmosphere.

Modern Harley gas caps also vent but only one way. They allow air in as gas drains into the induction system whether it is a carburetor or electronic fuel injection. Gas cannot feed out of the tank if a vacuum is created in the space it vacates. This is why air must vent in. Please see Volume III: *The Evolution: 1984 to 2000,* Chapter VI: *Fuel Delivery*, sections, *The Evolution of the Gas Cap* and *Fuel Tank Venting* for comprehensive examination of these topics plus pictures of disassembled gas caps. I know, this simple subject sounds like I am examining minutiae but the subject is a long way from simple as the lowly gas cap employs many principles of physics and the motorcycle will simply not operate without this pinhole with valves.

Later-style caps prevent environmentally dangerous gasoline vapors from venting. These vapors feed back to a vapor valve (62150-85) that often locates right by the bank angle sensor in one of two basic ways.

Some aftermarket gas tanks, like most Sporty and Softail replicas, have a standpipe. This metal tube runs inside the gas tank from the gas cap bung-tank down to an outlet at the bottom of the tank.

1. Stock H-D tanks generally have the vent underneath the dash panel. I have never liked this system because it is too close to the electrics like the wiring and the ignition switch. Electrical shorts and gasoline vapors can have very explosive relationships.

The gas cap screws into the gas cap bung. The portion that the standpipe connects to is always above the gasoline level inside the tank, no matter how much fuel is in the tank. A rubber line connects to the outlet at the bottom of the tank or under the dash as the case may be, and routes to a vapor valve usually located near the center frame down tube if on a Softail. Rubbermount Dynas and FLT models do not have a frame down tube but the vapor valve will be located most times on the frame body that angles back and down to the rear of the gas tank.

The subject of the vapor valve eludes many mechanics. I recently wrote one of my Techline columns in 2009 for American Iron Magazine about the vapor valve. No one at the mag knew what a vapor valve was and consulted local shops and dealers. They too did not know what I was talking about until I gave them the part number and where they could find it on a bike in their stores. Ohhh, they all exclaimed!

The rubbermount models, particularly later year ones have a fitting on the gas cap bung above the tank on the outside. A fuel door or a gas tank shield covers the raised gas cap bung with these tanks. A rubber hose will connect to this fitting. It then runs back and connects to the top of the vapor valve.

If the bike tips over too far beyond the riding lean angle, the vapor valve prevents gasoline from escaping through the vent. Two-safety reasons account for this.

The first is there will *not* be an expanding puddle of gas running out onto the ground and evaporating around a hot engine if the bike falls over.

2. The second is to direct venting evaporating fuel away from the hot engine and the rider. An electrical short, a lit cigarette, or other causes can ignite the vapor.

A hose connected to the bottom of the vapor valve directs the evaporation away. This hose leading away from the vapor valve routes downwards and vents into the atmosphere above the rear belt on older FLT models. Other Harley's have the vent tube go to a fitting on a frame member. The evaporated emissions feed inside the frame tubing. They can escape out through open frame ends that are uncapped. The goal is always the same: get the flammable vapor away from the rider and any engine or exhaust component that has potential to ignite it.

California Vapor Re-burning

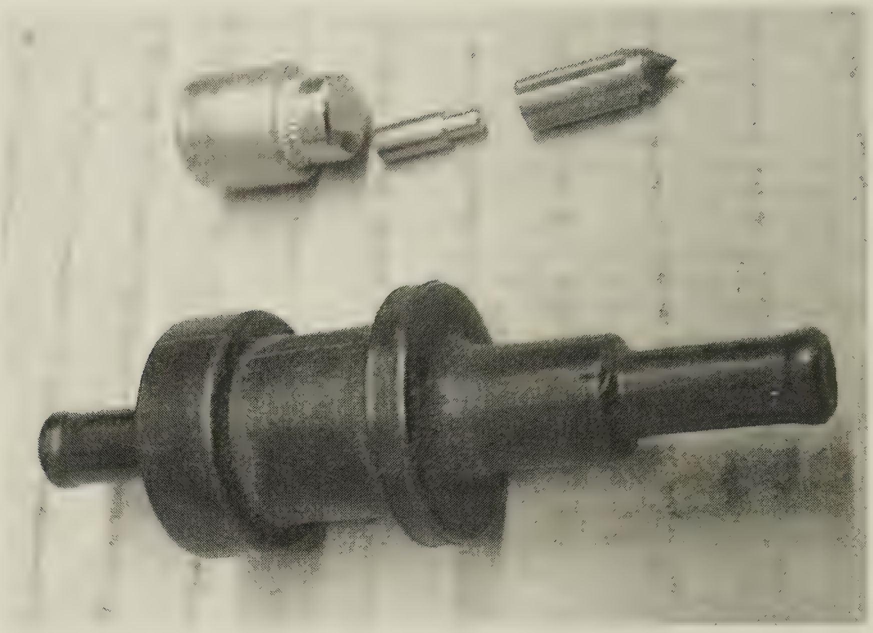
Gas vapor is a pollutant. California generally leads the way in dealing with harmful emissions. Emissions controls introduced in this leading edge, environmentally progressive state will generally spread to the rest of the country and Canada later. By 2010, most Harley's from 49-State production have adapted all the California emissions standards.

On Harley-Davidson's produced for California the secondary vent tube from the vapor valve is fed into a charcoal canister (27042-84A) where the fumes are stored if the bike is not running. When running, the vacuum…negative pressure…created in the carburetor venturi throat will draw the gasoline vapors from the charcoal canister up another hose called a purge hose back to the carburetor where they are ingested and burned in the combustion chamber.

The charcoal canister on California bikes must deal with another source of gasoline vapor. Gas fumes also hang around the induction throat, more so in a carburetor than with EFI. These vapors originating inside the carburetor throat draw through a hose connected to a fitting in the inboard or backside of the air breather backing plate called the clean air inlet. This hose also feeds down to the charcoal canister-holding container drawing fresh air down the clean air outlet to assist in purging the vapors in the canister back up to be re-burned. An electrical solenoid (28827-96) opens a butterfly seal on the backing plate when the ignition turns on to open the clean air inlet. When the ignition is off, the solenoid butterfly plate closes the opening to the clean air inlet in order to attempt to seal any hydrocarbon vapors in the air cleaner.

In addition, crankcase-venting vapors also feed into the air breather for re-ingestion into the engine. Those vapors that are not sucked in via venturi vacuum also feed into the clean air outlet and flow into the charcoal reservoir.

Both crankcase and carburetor throat fuel vapors that feed into the canister also draw up the purge hose, as described earlier, to the carburetor where they burn. EFI models do not have the same level of vapor wandering, as do the carburetors that rely on the physical laws of nature to operate. EFI injectors spray gas under pressure in controlled bursts into the combustion chambers.



Twin Cam Emissions Gasoline Vapor Valve

The vapor valve (62150-85) is a safety feature. It is a one-way mechanism designed to stop gas from flowing out of the tank onto the ground if the bike tips over. At the same time, it must let out venting fuel vapors to dissipate harmlessly into the surrounding atmosphere away from the hot exhaust pipes and engine. A tube connects a gas tank vent to the vapor valve, which is usually located on a frame member to the rear of the engine out of harm's way. On California bikes, the venting vapors feed into an emissions charcoal canister for purging back into the fuel induction throat for burning in the combustion chamber. If the vapor valve bracket that holds it in its upward correct position breaks or a mechanic installs the valve upside down, the internal valve mechanism will block any venting gas. This can result in an excessive build-up of vapor in the gas tank. If the vapor cannot find another way to escape and equalize pressure, excessive pressure buildup in the gas tank can force excess fuel down into the carburetor. This fuel will flow out of the float bowl vent onto the engine. EFI fuel tanks may suffer built up pressurized gas vapor forcing past a seal or gasket. The longer portion of the vapor valve must face vertically upwards to function correctly as designed.

Actually, a defect in the early Magneti Marelli fuel injection does not do this exactly as the injectors point in the wrong direction, but the much-improved Delphi system introduced circa 2001 corrected and enhanced fuel delivery. Delphi upgraded injector angles from 8° to 25° in 2006 making them even more efficient. Air flowing through the intake runner of the EFI system ably assists in taking errant vapors into the cylinders for burning.

Vapor Valve

Whether the vapors vent to outside atmosphere to the rear of the engine or into a charcoal canister to purge and burn in the combustion chamber, they must go through the vapor valve.

The vapor valve is another one-way regulating control device with an internal solid cylindrical weight with a valve and seat arrangement. A light spring sits underneath the weight, which sits under a guide that sits inside the needle on top.

The needle is similar to one found in a carburetor float bowl. The needle can mate in its respective seat that is part of the plastic housing *when the vapor valve turns on its side or is upside down.* When on its side the spring can close the valve on its seat. If upside down, the weight will take over and firmly close the needle into its seat.

At first glance, one would think that these parts are in upside down since gravity prevents the needle from mating with the seat on top of it. It is exactly as designed. The fuel vapors and vented crank oil vapors need to flow past the needle and seat arrangement at will when the bike is upright to dissipate into the air behind the engine and away from the hot exhaust pipes or safely into the California emissions charcoal canister.

- If the bike falls over the weight, assisted by its spring, gravity will press against the needle guide pushing the needle into its seat. The vapor valve will now block liquid gasoline that may flow out of the gas tank from proceeding any farther.
- If installed upside down by an errant mechanic or its hold-down bracket fails to secure it in its proper upward position, the valve and seat will prevent vapor from going through the valve. This can result in an excessive buildup of vapor in the gas tank. If the vapor cannot find another way to escape and equalize pressure then excessive pressure buildup in the gas tank can force fuel down into the carburetor.
- Normally the float mechanism will stop excessive flow and act as a dam against more fuel coming into the carburetor. A float is an airtight hollowed out donut-shaped apparatus made from very light and thin metal-like brass. Some aftermarket ones are solid, made from a non-porous light material that floats in a liquid.
- The float regulates the float bowl and its fill amount. The attached needle regulates the float up to its pre-set level. The Factory or a mechanic adjusting the float level usually does so by bending the thin metal tab protruding from the float that attaches to the needle. This mechanism keeps a reservoir of gas at the ready to draw up into the carburetor venturi via negative pressure (vacuum), created by air moving through the venturi. As gas draws up, the float lowers, lifting the needle out of its seat allowing more gas to enter via the force of gravity to fill the reservoir. Once the float reaches the adjusted level it prevents more gas from entering by forcing the needle down into its seat in the fuel inlet fitting.

The M-1093 safety-recall code 01011 concerning the vapor valve involves bracketry that fails to stabilize it in the up and down position. The defective bracket on affected models may allow the vapor valve to tilt to the point of allowing the vapor needle to close in on its mating seat; thereby blocking evaporates from venting into the atmosphere on 49-State models and into the charcoal canister on California models. This could cause the engine to quit or stall when still riding in an upright position particularly on carbureted models.

A buildup of vapor in the gas tank can put downward pressure on the gasoline, forcing it down into the carburetor below, overwhelming the float mechanism, and pouring raw gasoline into the engine and out the float vent. Raw gas does not burn and will cause the spark plugs to gas-foul with a flat-black fluffy residue, insulating the electrodes so the spark cannot jump to ignite the fuel, thereby stalling the motorcycle.

The float vent is a small hole drilled into the carburetor body above the maximum float setting. Gas runs out of this hole down onto the engine in early Harley's or into a vent tube on subsequent models that direct the gas away from the hot engine or exhaust pipes.

The vent tube may also attach to a fitting above the float bowl setting on some carburetors like the CV; there is a standpipe that protrudes from the bottom of the float bowl up through the gas past the float.

The vent hose on modern Harley's will run into the carburetor backing plate so that vapor can burn off. Of course, any amount of gasoline flowing through this vent will foul the plugs and prevent the engine from running.

On EFI models, the pressure will build up in the gas tank but will not overwhelm the fuel pump that delivers the fuel to the injectors. Buildups above atmospheric pressure will always seek out the weakest sealing link and eventually escape, perhaps causing parts damage. Certainly, seals will wear prematurely.

Leaking vapor near hot parts is always a safety concern. Fortunately, once the motorcycle is in motion, flowing air will usually disperse any evaporation safely.

The whole point of the recall is to bracket the vapor valve securely in its upright and correct position. This was really the second recall issued regarding venting on the new Twin Cams.

Another Blocked Venting Recall: Plugged Vent: 1999

Most venting problems involve a kinked vent hose or a blocked vent. However, the two recalls issued with the advent of the Twin Cams required a little more detective work than normal, as they were manufacturing missteps.

The first Service Bulletin M-1085, Safety Recall Code 098, issued on August 4, 1999, was a follow-up to Service Bulletin ML-366 and applies to 49-State Screamin' Eagle FXR's, Dynas, and Softails built between April 27, 1999 and June 6, 1999. It involves a possibly plugged gas-tank vent line connector (61131-92). It is likely that this condition can result in overflow gas from the carburetor.

The carburetor overflow hole on these models is the standpipe type protruding up through the gas from the base of the float bowl. If gas flows out this vent standpipe hole and eventually onto a hot engine via the air cleaner, safety certainly becomes a concern.

The recall affects the last Evo production models and the first Twin Cams. This is not as strange as it may sound to some. H-D production really divides into half-years. New design changes for the following year, many times introduce in the last half-year production of the previous year. This particular one bridges the change to a new powertrain.

Part number 61131-92 is a vent fitting that fits into a frame member so that the secondary vent hose from the vapor valve can feed fumes inside the frame for safe dissipation through the hollow frame members and into the atmosphere out uncapped ends of the frame away from hot components.

The recall does not apply to California models because the vapors do not feed into a fitting in a frame member but to the charcoal canister. They then purge back up into the carburetor for feeding into the combustion chamber. Furthermore, the recall does not apply to EFI-equipped motorcycles because carburetion exclusively serves the FXR's, Dynas, and Softails in these years.

The possible obstruction in the vented gas tank connector is plastic. The Factory estimates that perhaps this situation affects only 8% of the recalled bikes but better safe than sorry. H-D is checking the other 92% of the bikes recalled to ensure servicing of all affected bikes. Furthermore, Mother Harley lays down the law to its dealer network, telling them to perform the service whether they sold the bike or not. It is nice to see stuff like this. Harley is checking every bike just to be safe even when they have the problem isolated to certain production runs.

They were pretty sure, which bikes to fix but are going to check the other 92% of production to ensure none slipped by. H-D is demonstrating real corporate responsibility here and it is gratifying to see.

The Fix for a Plugged Gas-tank Vent Line Connector

A plastic flashing blocking a vent fitting during manufacturing needs clearing. Proceed with the following:

1. Straighten out a large paperclip with a diameter of about .060" ($^1/_{16}$").
2. Using a metal or wire cutter, snip an end at a 45-degree angle to ensure it is sharp.
3. Bend one end of the extended paperclip about 1 ¾"-long inwards to the longer piece If fixing a Dyna or FXR. Bend the end a shorter distance if fixing a Softail model because of space restrictions.
4. Next, take a $^1/_{16}$"-drill bit and some masking or electrical tape. Fold the sticky side over the drill-mounting end of the drill bit and stick both sides to each other. This will prevent the drill bit from dropping into the frame member particularly on the Softail models.
5. Stand on the left side of the bike and locate the vapor tube-vent line.
6. Disconnect this vent line from the vent fitting in the downtube frame member above the passenger foot peg on Dyna models. The FXR vent tube fitting is on the left side of the bike at the rear of the lower frame cross member. Following the vent line makes these easy to spot.
7. On the Dyna or the FXR, insert the long end of the paperclip into and through the connector. If there is no resistance, the motorcycle has not been affected; continue anyway since it is better to be safe than sorry.
8. Push the paperclip in with enough force to puncture the plastic flashing. Run the clip back and forth opening and enlarging a channel through the flashing. Insert the $^1/_{16}$"-drill bit into this opened channel and run it back and forth while running the bit through your thumb and forefinger to approximate a drilling action. This will ensure the channel is open and clear.
9. On Softail models, remove the two bolts and their respective flat washers to release the bottom black molded extension of the rear fender in front of the rear wheel. Bend this flexible piece back to the wheel and hold it there. At the rear of the shock mount on top of the rear swing arm is the vent fitting. Again, it is easy to locate if following the vent line.
10. Remove the vent hose from the fitting.
11. Repeat the above procedure except insert the short end of the sharpened paperclip. Space restrictions require this. This is also, where the masking tape comes in handy to prevent the drill bit from falling straight down through the vent fitting into the swingarm. However, if it falls in it's no big deal except for losing a drill bit.

12. Reattach the fender extension.
13. Always use red Loctite along with specified torque values, as vibration is very efficient at loosening bolts and nuts.

Venting in General

A gas tank and the fuel delivery system venting are essential for the gas to flow out of the tank via gravity and into the carburetor. In bikes equipped with electronic fuel injection, gas feeds under pressure via an internal fuel pump inside the gas tank. Excess gas pump-returns to the tank.

On either system, the gas tank still needs venting to let air in to fill the vacuous space left by the exiting gasoline. The EFI pump will override some of the laws of physics for a time, but the system will begin to suffer the consequences of any physical violations.

There have always been venting problems; sometimes a blocked by dirt vented gas cap prevents air from entering the gas tank to replace and fill the emptying area left by gas flowing out.

On a carbureted bike, the gas cannot exit the fuel tank via the gas petcock if the vent is blocked, thus leaving a vacuum. The force of the sucking vacuum seeking to be filled with gas or air…it does not care which…will fight to counteract the gravity force-feeding the carburetor. Principles of physics will interfere with and/or prevent its exit. Carburetors are all about the Laws of Physics. If one wants to understand venting and carburetor air/fuel delivery it is necessary to have a thorough knowledge of basic high school physics. Air must flow back into the reservoir through the vent from outside the gas tank.

Dual tanks like those used on Evolution and early Twin Cam Softails also had two connecting hoses between the tank halves. There is one at the front of the tanks at the bottom, which allows fuel to flow from one tank to the other so that each tank will have the same amount of gas in it when the bike is vertical. Of course, when on its sidestand more gas will flow into the left tank as the liquid seeks to level. The weight of the atmospheric pressure will force the higher level of the gasoline on one side of the tank to enter the lower side until atmospheric pressure equalizes in both tanks. This is why a liquid will always seek its own level to equalize pressures.

A simpler way of looking at it is the weight of the gasoline over the exit connecting hose creates pressure to force gas through the hose until the weight (pressure), equalizes in both tanks. Harley-Davidson takes advantage of this physical principle to utilize only one outlet for two separated gas tank halves. The gas only flows out of the petcock located in the left tank at the rear near the bottom. The right tank needs to empty and balance its reservoir into the left one to keep a constant supply of fuel on hand.

This equalization hose is also required on single gas tanks if they have a hump in the middle so the tank will fit over the top frame member. If this hose is necessary then a vent will be also. The gas cap, if vented, will satisfy the demand in this particular case if air can flow over the internal hump. If not, then a vent line between the tanks will be necessary.

Between split tanks, the vent line travels from one tank to the other at the top front just to the front of and below the speedometer. The speedometer housing hides the vent line from view.

When troubleshooting a vent problem on a dual split tank system, ensure the gas cap vent is okay. I always ask the owner if there is a recent removal and reinstallation of the gas tanks. If so, dollars to donuts, my money says that the wrench kinked this line. However, this is normally problem-free once properly installed and then left alone; but Harley riders are always taking their gas tanks off for one reason or another.

This would not have been the problem referred to in the FLT service recall since FLT tanks are single tanks and do not have the hose I am referring to. Neither would this situation have applied to the other recall even though the early Softails have split tanks. Logic and mechanical deduction would accurately deduce the same for Dynas and FXR's as they also have single gas tanks.

Identifying and tracing symptoms as well as applying logic to a wide knowledge base will lead the thinking mechanic to the cause and thus the fix. *Thinking* is the key word. Those that do not think a problem through inevitably attempt to patch a symptom not fix the cause.

Carbureted Gas Petcock Blockages

The petcock, a shut-off valve, located at the bottom rear of the left tank or the left side of a single tank, is not at the absolute lowest point but close to it in order to allow heavier sediment in the fuel to settle below.

Where does this sediment come from? Oxidation (rust), of the motorcycle tank insides, over spray when the tanks are painted, dissolved paint chips from the gas cap bung, and of course, impurities in the gasoline itself all contribute to this problem.

Always patronize a busy gas station. Ones that do not pump much fuel will have higher water condensation buildups in the fuel, more sedimentation from oxidation inside the stations holding tanks and separated chemicals in the gas. For example, alcohols (ethanol and methanol) just love to separate from the gasoline.

This simple petcock location methodology seeks to prevent sediment interfering with gas flow through the fine filter inside the tank attached to the petcock. The filter captures floating particles and prevents them from interfering with the float mechanism in the carburetor.

The float is a hollow donut-shaped part that floats on top of the gas in the float bowl normally located at the bottom of the carburetor. The attached float needle that sits in the entrance way is adjusted to allow gas to flow into the float bowl until the float donut tops out and prevents more gas from coming in. This allows a reservoir of fuel to be available at all times.

Sediment can lodge between the float needle and its seat, causing an overflow of gas into the carburetor when not needed. This overflow may foul the spark plugs but will also find its way out of an overflow hole, usually on the side of the carburetor above the normal position of the float. Gas will flow out this hole and down onto the engine on older Harley's. H-D wisely put a fitting into this overflow hole and attached a hose onto the fitting. The hose must direct away from hot engine parts and the exhaust so that the overflow harmlessly deposits onto the ground, not that gas is harmless. I am sure this simple hose attachment has stopped many an injury or deaths and protected the manufacturer from an ever-increasingly litigious public.

The Fix: Venting Diagnosis

Many times mechanics and riders alike confuse a venting problem with an electrical one.

Harley people seemingly love to go to the most complex fix, often overlooking the simple one. Electrical problems present a mystifying and complex fix for those that lack knowledge. It can go on forever especially when it is not the cause of the problem.

1. When confronted with a bogging down or engine-stopping situation while riding, simply loosen the gas cap and carefully continue. If the bike perks up and runs normally, there is a venting problem.
2. If it does not, then visually check for sediment blockage of gas flow in the external gas filter if there is one. If obstructed, clean. Sediment is not a venting problem but a blockage one.

3. The internal petcock filter will probably also be blocked or partially blocked. Gasoline will have to be drained and the petcock removed for examination and cleaning.
4. Flush or blow the tank(s) with compressed air to get rid of the sediment.
5. Most gas tanks have a sealer inside to prevent oxidation and leaks. The sealer may be flaking off. Visually and thoroughly inspect with a bright flashlight. If this is occurring, the problem will be ongoing as there will be a steady supply of sediment to block the filtration and/or the float.

Gas Tank Sealing

This is an irritating and time-consuming repair. Many service departments will simply replace the very expensive painted tank. I am a repair kind of a person who knows that not everyone has lots of money.

Removal of the material is laborious and painstaking. Shaking the tank with non-ferrous objects like marble alleys inside will help it flake off faster. Compressed air is a great assist. Reseal the tank with a three-stage sealer:

1. The first step is a cleaner.
2. The second etches the metal.
3. The third seals it.

If you want to get high or risk an explosion, as the sealer is volatile until it dries, do this in a confined space. The high will also produce a pounding headache, so do the procedure outside.

The sealer takes about twenty-four hours to dry. Always be conscious of the gas tanks welds, particularly at the bottom. Make sure lots of sealer dries in these locations.

Also, ensure that sealer has sealed all parts of the tank(s). Gently swoosh the sealer thoroughly all round the inside. I set the tank at different angles every hour, or so, to ensure a comprehensive job. Yes, you can go to bed as long as you did not start the process just before bedtime, since by then the sealer will be tacky and not flow anymore.

Sediment Restricting Gas Flow

If there is no external filter to inspect, as Harley's do not come stock with them, remove the gas line with the petcock turned off. Direct the gas line into a bottle or can and turn on the petcock to observe gas flow. It may flow fine at first, then start to slow down and may even stop. Sometimes the sediment floats in the gas but the outflow current attracts the sediment to the filter and blocks it. When there is no outflow, the sediment may re-dissolve into the gas away from the filter. Let the gas flow for a few minutes to ensure this is not the case. If flow reduces or stops, repeat the above fix procedure.

The bottom line is if there is no venting permitted for whatever reason, the gas cannot flow steadily out of the tank into the carburetor. This will cause the motorcycle to hesitate or quit. This can be very unsafe at an inopportune time, especially with inexperienced riders.

The venting problems referred to in both service bulletins were initially much more difficult to figure out since there was no rhyme or reason to them as they were manufacturing errors.

Initially, the Bank Angle Switch sensor was difficult to diagnose because H-D riders and mechanics were just adjusting to engine management systems and their sensor network. The Bank Angle sensor (32495-98) was new for the 1999 Twin Cam so most had no clue that it even existed in the first months of riding before service manuals were readily available. The engineers did not even teach me about the bank angle switch while I was in Milwaukee for my intense and comprehensive education about the new Twin Cams. This initially complicated problem was very difficult to diagnose because no one in the Harley world had ever experienced a switch that would turn a bike's ignition off if its bracket broke.

There were other service advisories and minor recall notices like those dealing with speedometer face blemishes, handlebar, and faring issues related to comfort or rider size; just the normal stuff every manufacturer goes through fine-tuning the product.

Pinion Shaft Noise

Is it from the timing chains?

Twin Cam Engine Noise

Well, let me start be saying that this is most peoples' presumption. Having no experience, and who does at this point in 1999, with the noise emanating from some but not all Twin Cam 88's, most wrenches are blaming the timing chains. My personal Roadglide has this noise. In 1999, Harley mechanics do not know what to make of this.

It was time to consult with those that do. An excellent Japanese mechanic I know instantly diagnosed this as a timing chain problem. I responded by saying that the chains were supposed to be silent. The whole reason for eliminating the Evolution and earlier model timing gear setup was to comply with increasingly stringent EPA noise restrictions. This was a priority, from Day One, in the development of the new Fathead engine.

On discussing this with two H-D engineers while at the York plant, a different perspective emerged.

They, too, thought the noise coming from some but not all Twin Cam 88's was from the timing chains. Maybe they had stretched. This was not logical since the six adjoining plates that comprise the chains are very strong. Furthermore, there are spring-loaded tensioners to keep them properly adjusted as wear occurs. The engineers found the ones they took apart were fine.

1. Ahh, maybe the chain-to-cam sprocket fit was at fault. The sprocket does look crude relative to the chain, which appears to be precise. No, that was not the problem either. The fit was just fine. Well, it has to be something in the timing chest.
2. I learned a long time ago that the Harley engine is a master at transferring noise from one area to another. The most famous example is a worn primary case-compensating sprocket transferring a relatively harmless knocking sound into the engine's bottom end, which if it were true would be extremely harmful. Similarly, a worn lifter can make its voice heard a foot away in the top end.

Yeah, maybe it is the oversize pinion bearing causing the noise? The engineers told us that the problem was driving them batty as they kept returning to the timing chains as the obvious cause. Time after time, everything checked out.

1. Finally, they split the engine cases in exasperation. Maybe, it was the new pinion bearing that was somehow causing and transferring the noise into the timing cavity. It checked out fine. I am thoroughly impressed by this humongous support bearing that will probably take a few hundred thousand miles to wear out.
2. Finally they found the cause! On some models, the fit between the new larger diameter pinion shaft and the inner diameter of the huge pinion bearing is a little loose. I never heard these noises on the prototype test bikes when I was in Milwaukee last March in 1998 while the engineers taught us about the new engine.

3. Why is there a difference on some production models? Well, there is a big difference in building a couple of hundred prototype models to close specifications and making, say, fifty thousand production models on the assembly lines for you and me. Production tolerances between parts allow slightly greater variances. The rules of thumb are basically, what you can get away with and still have a reliable product.

The engineers found that by making a one-thousandths of an inch (.001"), thick bushing, and placing it between the pinion shaft and the inner diameter of the bearing that the noise disappeared. Future production will tighten up this tolerance.

Whistling Pinion Bearing

I have had discussions with Skip Metz, the Powertrain Program Manager at the Factory.
He is a very proficient, hardworking engineer and a huge asset to Harley-Davidson.
In short, this guy knows his stuff.

Twin Cam 88 Timing Chest Noise

He wanted to clarify a reason for the noise generated out of some timing chests in early production models of the Twin Cam 88. I am certainly interested in this since my own 1999 FLHTR generates almost the same amount of noise as my '54 Panhead. I'm kidding, it is noisy but not that noisy.

Whistling Pinion Bearings are fixed after Sept. 25, 1998

Before getting worried about this, let me say that the Factory corrected this situation on all affected rubbermounted models produced after Sept. 25, 1998. There is a fix for models like mine, made before this date; more on this subject a little later.

This was no problem on rigid-mounted-engine Softails as they came into production afterwards.

The Source: Pinion Bearing Rollers

After eliminating the timing chains and mating sprockets as the cause, the engineers started to look at the humungous pinion bearing as a possible source. This bearing supports the right side of the crankshaft. The pinion shaft goes through the bearing and protrudes into the timing chest. The rotating pinion shaft ultimately drives various components such as the oil pump and the cams.

To make a long and frustrating detective story short, Skip had a bushing made to replace the bearing in a test engine. Voila¢, the noise disappeared. Now the problem noise had been isolated. It was definitely coming from the pinion bearing. Nevertheless, the question of how remained.

The Cause: Loose Fit Rollers

Skip and his fellow engineers determined that when the cylindrical roller bearings were rolling, there was no noise if the rollers were *loaded* and could not move *axially.*

Loaded means there is pressure on the bearing against its cage so it cannot rattle and make a noise.

1. If the crank pin were in the up and down location, like say, at 12-o'clock or 6-o'clock, there is a load on the rollers and therefore no play between the roller and the cage.
2. When the crank pin is sideways at the 9-o'clock or 3-o'clock position, there is temporarily no load on the rollers. The reason is that the load is changing direction or force. In these positions, the rollers can move within their cage.

A second factor now comes into play.

Gases transfer between the inside of the crankcase and the timing chest because of displacement caused by ascending and descending pistons.

3. It is simple; the incoming gases displaced by descending pistons from the crankcase through the pinion bearing into the timing chest rattle the rollers inside their cages when at the nine and three-o'clock position since there is no load on them.

Okay, but how do we eliminate this noise now that we know what is causing it?

The Permanent Pinion Roller Whistling Solution

Skip and the boys then looked at the axial play between the bearings and cage.

1. It measured, on average between six and twenty-two thousandths of an inch, (.006" to .022").
2. Furthermore, the noise did not start to occur until the clearance reached about .014".
3. Harley, then directed the bearing manufacturer to reduce the tolerance on all new bearings installed after Sept. 27 1998 to between .002" and .008"

Like Skip says, "Shake the old loose tolerance bearing and it sounds like castanets being played while the new bearing is silent to the ear". [2]

This permanently cured any excess noise caused by this particular situation. The extra play is not a mechanical problem but a government driven noise emissions one. Noise usually indicates a mechanical problem that requires addressing but not always.

The Temporary Whistling Roller Fix

For those of you, like me, that have this problem noise in our bikes, there is a field fix on an as-needed basis. That means Harley will supply a restrictor plate that fits inside the engine case casting that shuts down some of the gaseous air flow through the loose tolerance bearing. This, in effect, dampens the rattle.

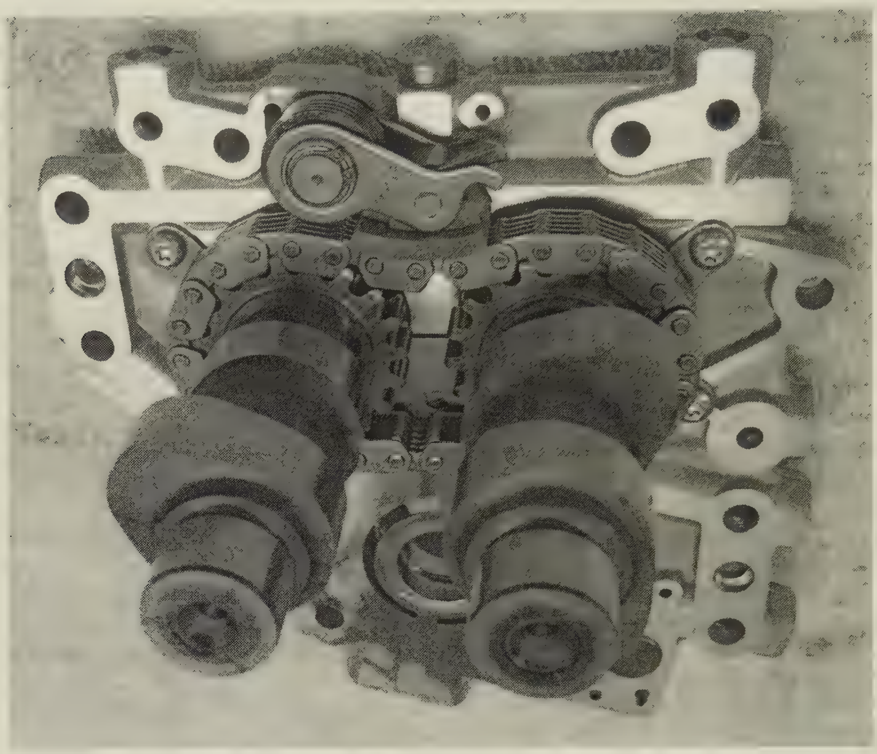
I just figured out now in 2010 when editing this 1999 article that the restrictor plate might have also reduced or cured some oil blowby also known as oil carryover or venting problems that began to plague some Twin Cams for many years. Of course, oil venting outside the breather cover was an unknown problem beginning in 1999 but not for long.

Engine Durability

Skip says that if your bike has one of these loose tolerance pinion bearings not to be alarmed. "Engine durability is not affected," [3] says the brilliant designer of the Fathead engine. I have to agree with him. I never had any doubt that the bearing in my bike still would not do at least one hundred thousand miles; it is just that I would have to listen to it.

I will put in the restrictor plate while I am fixing the cam bolt that has had a recall on my bike also. I might as well replace the suspect rear-cam sprocket with an upgraded Andrews's one while I am at it.

However, I was still unaware of the impending rear-cam-outboard-journal ball bearing problem.



1999-2006 Twin Cams in Cam Support Plate

Pictured is the inboard (inside) view of the 1999 to 2006 cam support plate. Between and below the cams, part of the pinion shaft bushing (25344-99) is visible. The pinion shaft, which is integral with the right-hand flywheel extends through the supporting pinion bearing (24623-99) located in the right-hand engine casing. The oil pump (26035-99B) sits on and is driven by the rotating pinion shaft between the engine-casing-wall separating the crank from the timing chest. The oil pump (not shown) is bolted to the inboard of the cam support plate below the cams. The inboard camshaft journals at the end of the shafts shown above sit in and are supported by two INA caged needle bearings (H-D 9198) set into the timing compartment side of the right engine casing. The secondary cam timing chain (25607-99) is shown connecting the two cams on their respective chain sprockets. The secondary timing chain spring-loaded chain tensioner (39964-99) is supposed to keep the timing chain constantly and correctly adjusted.

Cam Bolt Problems

Those of you affected on production bikes built before September 28, 1998, will be receiving a Harley-Davidson recall notice regarding a cam bolt problem fixed on all Twin Cam engines produced on or after this date.

The Problem

Inside the timing chest on Fathead engines, there is a small ¾"-long, $^5/_{16}$"-coarse thread bolt (H-D 898). This bolt, along with a flat washer (H-D 6278) holds down the 34-tooth cam drive sprocket (25563-99) that turns the two cams via two *silent* timing chains. On early models produced before September 28, 1998, there is a chance that the head of the bolt may pop off because of too much stress. Skip Metz, the Powertrain Program Manager in Milwaukee, describes the problem this way: "For a variety of reasons, an inconsistent clamp load could result when the cam bolt was installed to the specification setting of 23 ft-lbs. Under some operating conditions, this could allow the internal engine timing chest drive sprocket to slip on the cam which in turn causes the pinion shaft timing key to "hog" out, which puts an axial load on the timing bolt, stretching it until the head popped off." [4]

My personal familiarity seems to indicate those who are very hard on their new engines experience this first.

I will explain Skip's engineer-speak in English. The impact wrench that installs the bolt is set to 23 ft-lbs of torque. Because of variables, I am about to explain, the torque applied to the bolt did not give the clamp load needed to hold the parts together properly.

This torque specification was very precise, but factors listed below were robbing Harley of the accuracy needed. Again, Harley-Davidson, very conscientious about correcting any Fathead engine glitches immediately, has addressed this problem already.

Design problems are another case entirely, which can take many years first to acknowledge then to correct by a redesign. The most dramatic example is the timing chest chain and tensioner situation that finally went through a redesign in 2006-2007.

Confusion about these mostly minor teething problems arises because trusting Harley riders go to their dealers for information. The problem is that the Fathead engines are so new that the dealers do not have enough information yet to adequately deal with some of the customer queries.

What Happened to the Cam Bolt?

1. First, initial use of a dry Loctite on these original bolts, which turns to liquid by the friction and heat caused by turning or torquing the bolt, is not consistent.

The friction gave an inconsistency to the clamp load applied to the joint. In other words, the desired torque became a hit-and-miss proposition.

2. Second, the bolt threads right up to the head. This is not normally a problem, but the threaded portion of a bolt is weaker, by nature, than any portion not threaded.
3. Lastly, the stamped metal washer, fitting under the bolt head, gives a flat surface but not always a *perfectly* flat surface.

The Fix for "Popping" Cam Bolt Heads

1. Firstly, Skip and his fellow engineers, switched to a liquid Loctite, which does not add significant friction to the torquing process.
2. They also put a dab of oil under the head of the bolt, again, to remove any torquing impediment.

3. Next, new bolts have no threading for 1/8”-under the hex bolt head removes any stress concentration.

I know it is only 23 ft-lbs, but this is just a skinny little bolt that needs delicate treatment.

4. Lastly, the washer is ground precision flat to remove any chance of inconsistency that again affects torque. Stamping the washer out of metal ceased.

The Torquing Procedure: Torque Angle Control

No longer does the torque gun straight out of the gate apply a one-time 23 ft-lbs blip.

Skip’s foreign, engineer-speak language, comes in play once again as he says “Torque angle control is achieved by a new torquing procedure which….” [5]

Translation for Torque Angle Control

This relates to what happens to a tightened bolt and the physics of how it holds down the attached piece. If you think about it, a bolt will stretch a certain amount depending on how much applied torque affects it. It is the force that this prescribed stretch on the bolt imposes that Harley wants to control.

The new procedure is to torque the bolt to 15 ft-lbs, then tighten the bolt 12° more beyond that. The Factory was not getting a consistent clamp load with the initial procedure and bolt/washer design. Consistency is required. The new procedure along with the design changes will ensure that there are no more popping bolt heads.

Cam Sprocket Keyway

A keyway attachment holds the 34-tooth cam drive sprocket (25563-99), to the end of the outboard journal of the rear cam.

Powering the Timing Chains and the Valve Train

The silent chain drive system powers the cams rotation in the Twin Cam engine. The revolving pinion shaft in turn powers the timing chains. The pinion shaft is an extension of the right-hand flywheel extending through the huge pinion ball bearing in the inboard side of the right-side engine casing.

The rotating shaft turns and operates the oil pump (26035-99) that sits on the pinion shaft between the right engine case and the cam support plate. The pump bolts to the inboard side of the cam support plate. The pinion shaft turns the pump’s internal geroters. The inner geroters of the feed and return side of the pump have a flat spot on their otherwise round inner diameters that slide onto a similar mating flat spot on the otherwise round pinion shaft.

The shaft continues on and through the cam support plate (25267-99). The end of the pinion shaft just sticks through the cam support plate bushing (25344-99) in the support plate. Oil feeds to the bottom-end crank (flywheel assembly), through this bushing, via the pinion shaft center oil passage, and onto the right flywheel internal oil passage and up into the crank pin. The pressured oil out of the crank pin lubricates the crank pin itself, the bottom end bearings rotating on the crank pin and connecting rod journals that ride on the bearings

There is another flat plane on the end of the otherwise round pinion shaft. The 17-tooth pinion-drive-sprocket (25609-99) has a corresponding flat area inside its otherwise round inner diameter fits onto the end of the pinion shaft. The primary cam drive silent chain (25610-99) connects this 17-tooth pinion cam sprocket to the 34-tooth rear-cam-drive-sprocket (25563-99) attached to the end of the rear cam journal.

The flywheel pinion shaft rotates as one with the crank. The attached cam sprocket does the same, driving the chain and larger sprocket that also rotates the rear cam (25544-99 carbureted, 25297-99 EFI), supported by bearings at either end. All of this occurs on the outboard (outside) face of the cam support plate.

On the inside (inboard side) of the cam plate, the cast cam sprocket is part of the rear camshaft from 1999 to 2006. It is thinner, separate, and pressed on from 2007 to present. A secondary timing chain (25607-99) connects this inboard sprocket to a similar one on the front cam. To review:

The rear cam has an appendage (outboard journal) that sticks through the cam support plate to which the 34-tooth cam drive sprocket attaches via an integral keyway and clampdown bolt.

- A ball bearing (H-D 8990) in the cam plate supports the cam on its outboard cam journal.
- Just inside the support plate, is the secondary 1999-2006 integral cast-in rear-cam-drive-sprocket.
- The inboard secondary cam drive silent chain (25607-99), attaches over this integral rear cam sprocket and connects it to the front cam's integral sprocket, also supported by a ball bearing (H-D 8990) in the support plate. The bearings and thus the inboard cams are on the same horizontal plane beside each other.

Now, it is apparent how the cam sprockets and silent chains power the rotating elliptical cam lobes and so follows the whole valve train that actuates and closes the valves in the heads. One last thing:

- The chains need tensioning and spring-loaded tensioner pads do this.
- The primary cam drive-chain tensioner (39954-99) attaches to the outside of the cam support plate.
- The secondary cam drive-chain tensioner (39964-99) fastens to the inside of the support plate.

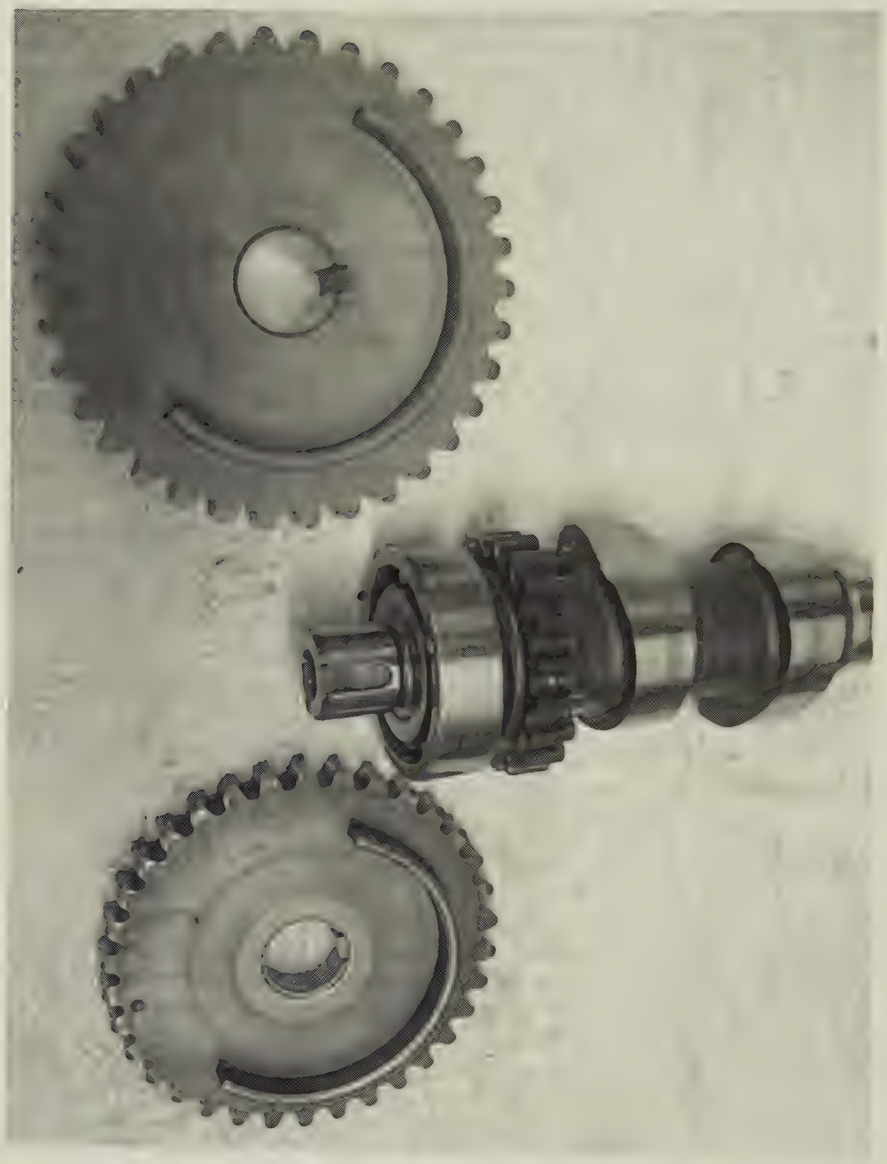
These 1999 to 2006 sharp-edged chains and brittle tensioner pads will prove to be a serious and ongoing long-term problem with the Twin Cam engine until the advent of the 2006 Dyna Glides. The edges are sharp from a mechanical perspective but not to the touch. As of 2011, the new chain system seems to be working well and is unequivocally superior.

Keyway Shearing in 1999

The 34-tooth cam-drive-sprocket is held in place by the keyway slot in the rear cam journal extension and a keyed protrusion from the inner diameter of the sprocket itself. The problematic, previously discussed, 1999 cam-bolt clamps the keyed sprocket onto the rear cam journal.

Now to the problem at hand, which is this 1999 primary rear cam-drive sprocket keyed to the appendage on the outboard rear cam. The hogged out female half-moon curvature in the cam-journal-adjunct is not the problem. Instead of using a separate half-moon key that fits into this keyway curve in the journal and a flat indent in the cam gear, the 1999 TC88 key is part of the gear.

This was a problem waiting to happen. It was probably manufactured this way as a cost-saving measure instituted by the bean counters. This keyway methodology was eliminated in 2000 in favor of multiple mating splines.



1999 Rear Cam-Drive-Gear Keyway Shearing

The top Andrews cam drive gear (Andrews' 288010) is the aftermarket answer to a shearing key in the 1999 Twin Cam timing compartment on the right side of the engine below the carburetor. The lower stock Twin Cam 1999 cam-drive-gear (25563-99) may shear especially with hard riding. The separate Andrews gear flat key indent is solid relative to the frail integral key cast into the H-D gear. The pictured rear cam (25544-99 carbureted, 25297-99 EFI) is fitted with the soon-to-be-replaced ball bearing (H-D 8990) over its outboard cam journal. Behind the bearing is the secondary cam "silent" chain integral cast-in drive sprocket followed by the rear intake and exhaust elliptical shaped cam lobes that direct their respective valves to open and close via the valve train. A valve train is required to connect the lower timing chest located cams dictates to the valves located above and inside the heads. The appendage in front of the cam bearing shows the hogged out female half-moon shaped keyway indent. The separate aftermarket key (not shown) is substantial in size and strength to resist shearing. This rear cam journal-support plate ball bearing (H-D 8990) soon proved to be very problematic, sometimes disintegrating under the imposed stresses. The initial reason for its use is a ball bearing is quieter than a roller bearing, inner race, and thrust washer kit (H-D 8993) that soon replaces it. The Twin Cam design evolved because of noise emission reduction dictates by the government. It is all about reducing mechanical noise emanating from the engine and transmission as well as exhaust racket and unbelievably, manifold intake air sound. The stresses on the rear bearing need a roller bearing to cope. Served well by the same ball bearing (H-D 8990) in the cam support plate is the front cam journal, which operates with less mechanical strain. The circular quarter-inch high ridge on both the H-D and the Andrews outboard sides of the rear cam drive gears is the Hall effect rotor. As the reader can see, the rotor (ridge) also known as a trigger wheel is near the outside diameter of the sprocket and it goes a little more than half way around the sprocket surface. The cam position sensor (32496-99) also known by its acronym CMP and its electrical wiring sits in a hole behind the timing plate of the timing chest cover (not shown). The CMP measures through magnetic pickup where rotationally this ridge's location is; when it begins, and when it ends. The cam-position-sensor magnet is known in mechanical theoretical lingo as an *impulse generator*. This sensor measures where the Hall effect rotor is located on the outboard side of the rear cam drive sprocket. This is called a *Hall effect transistorized ignition*, more commonly known as part of an electronic ignition system. The magnet generates a pulse of electrical current instigated by the ridged rotor. This pulse is used to trigger the electronic control module (ECM), which signals the ignition to fire the spark plugs. The CMP discontinues after a few years. The crankshaft position sensor also known as the CKP sensor that locates in the front of the left side engine case takes over CMP functions. Its magnet reads slots cut into the left flywheel rim to determine piston location and speed in order for the ECM to fire the spark plugs at the correct time. Both the CMP and the CKP are able to determine piston, cam, and valve movements because all internal engine parts of consequence time to each other.

With normal riding the integral key will wear out faster than a proper separate key fitting inside and between two adjoining and mating part indents. With hard riding, sudden acceleration, and/or gearing down excessively to slow the bike instead of using the brakes, the integral key cast into the cam drive gear may shear. High-performancing the engine will also lead to an increased shearing possibility.

1. If the key shears, the cam drive sprocket will be able to move on the end of the rear-cam-journal. This will lead to the cams slowing or stopping rotation altogether.
2. The second malady that may occur is the sheared-key gear may pop the head off the clamp down bolt allowing the gear to fall off and mesh with moving parts with all the destruction that will entail.

An excellent fix has been developed by John Andrews of Andrews Products Inc. (www.andrewsproducts.com) who if my fading memory serves correct started his innovative career with 1st / 2nd close ratio gears for the 4-speed transmission in the early seventies. Of course, I will be discussing this most popular performance conversion in Volume VI: *The Shovelhead: 1966 to 1985.*

Andrews Rear Cam Drive Gear

The Andrews fix is replacing the stock rear cam-drive gear with its weak integral key with his drive gear with a separate and stronger key and slot Andrews' part number 288010. The difference in quality from the stock gear to the Andrews' gear and separate keyway is readily apparent to the eye.

Harley realized early on that this integral key and gear would be a problem and corrected it in year 2000 with a multiple splined appendage on the end of the rear-cam-journal to correspond with a mating splined cam gear (25716-99). This simple and effective change has proven to be very successful.

Cam Support Plate Bearings

The Rear Cam Ball Bearing: 1999-2000

Hey, Donny:

My 1999 Road King just blew up. The dealer would not warranty the damage because I had put quality aftermarket cams in the engine. The shop that did the work is very professional and knows what they are doing so I do not think them or the cams are at fault. I need to know what is going on so I can argue my case. Enclosed are my old parts including the oil pump and the cam support plate for you to peruse.

Tom
Pissed off in Florida

Hi Tom:

Sorry to hear about your grief, but misery loves company and you are not alone. I am hearing a lot lately from many H-D riders about this situation. It is occurring with stock motors, engines with dealer installed Screamin' Eagle parts and with excellent aftermarket shops putting in premium aftermarket parts. It is happening no matter what the TC88 configuration.

The problem is not with the whole engine but with one compartment, namely the timing chest located adjacent to the bottom end on the right side of the engine. Harley-Davidson is saying that timing chest confinement of any problems will not affect the bottom end crank-compartment or the top end of the Twin Cam. [6] I will examine this claim more closely later.

The Cam Support Plate

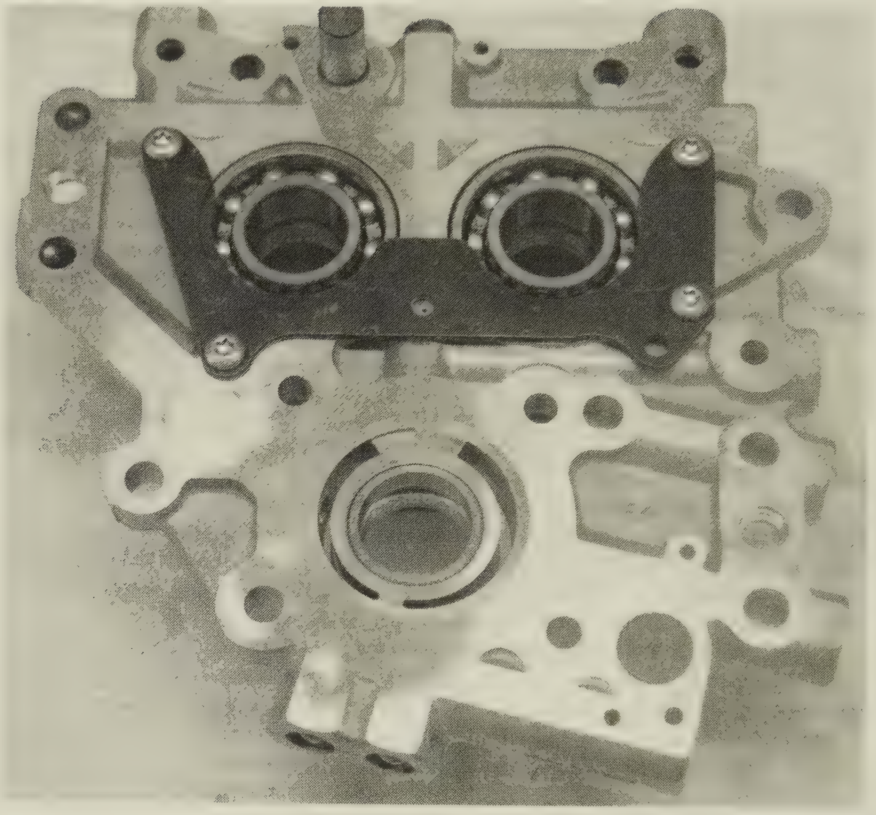
The cam support plate (25267-99) is located inside the timing cover essentially dividing the timing chest in half. It is about 6 ½" inches high at its longest point and around 6 ½" inches wide at its widest point with a varying thickness approximately ¼" to ⅝" in depth. It may visualize as a square plate because of the equal dimensions but it angles narrower towards the bottom. The cam support plate bolts to appendages cast into the right side engine case inside the engine-timing chest. There are six-hold-down Allen head screws (H-D 4741A): one inch long by quarter-inch NC (National Coarse), ¼-20 x 1" threads. The support plate sits about three inches out from the outside (pinion side), of the right engine casing.

The two cams, secondary silent timing chain with its spring-loaded adjuster and the oil pump sit between the inboard side of the cam support plate and the engine casing behind it separating the timing chest from the bottom end compartment.

The pinion shaft travels through this space from the bottom end compartment through the pinion bearing (24623-99) into the timing chest to just beyond the cam support plate (25267-99) on its outboard side. In fact it travels through the center of the oil pump (26035-99) driving (rotating), its geroters.

- The two cam drive primary chain sprockets also known as the 17-tooth crank (25609-99) and 34-tooth primary rear cam sprocket (25563-99), their clampdown bolts (H-D 898), the primary silent drive chain (25610-99) and its spring-loaded adjuster (39954-99), along with the chain guide block (39965-99), sit on the outboard side of the cam support plate between it and the inside of the timing cover.
- The only internal function of the timing cover is to dampen noise via ribs cast into the inboard side. The ribs interfere with noise travel.

A theoretical rider sitting on the motorcycle facing forward determines right and left directional references of the motorcycle, engine, transmission or other major components. The riders, left or right perspective delineates parts location. Therefore, the primary chaincase is on the left side of the bike while the timing chest is on the right. There is a left turn signal and a right and on it goes.



Problematic Twin Cam 1999 to Early-2000 Cam-Support-Plate with Ball Bearings

Pictured is a 1999 to early 2000 cam support plate (25267-99) with cam journal end support ball bearings (H-D 8990 x 2). The cam bearing retainer plate (35052-99) on the inboard side holds the bearings in place. When installed with cams, this side of the cam support plate faces inwards. Therefore, the ball bearing on the left is the front cam-journal support bearing. The ball bearing on the right is the problematic rear cam bearing. The stresses imposed by the primary (25610-99) and secondary (25607-99) timing chains and pushrods require a roller bearing, roller bearing inner race, and thrust washer kit (H-D 8983) on the rear. This roller bearing replaced the rear ball bearing in late 2000 necessitating an upgraded cam support plate (25267-99A, 25267-99B) also. A ball bearing support is suitable for the different stresses imposed by the secondary drive chain and the pushrods on the *front cam*. The *rear cam* has different stresses that include an angled primary timing chain ((25610-99) pulling on it, which a ball bearing has difficulty in coping with. The cam support plate has internal oil feed lines running from side to side as well as up and down and acts as the oil distribution center for the engine. The peg (dowel), above the front bearing holds the secondary cam chain tensioner (39964-99). The bushing at the bottom is the pinion shaft bushing (25344-99). Oil feeds through this bushing and into the pinion shaft for delivery to the crank pin, crank pin bearings, and the connecting rod races. The oil pump (26035-99) sits on the shaft, which also drives the pump. The pump bolts to this inboard side of the cam support plate via the four closest holes surrounding the pinion bushing. If replacing the timing chains with aftermarket gear drive cams this support plate with ball bearings would be appropriate. Ball bearings, front, and rear are suitable for the different stresses imposed by a gear drive. Strange, a ball bearing that is quieter can handle louder gear driven cam stresses well; a louder rear roller bearing is required to handle the stresses of the quiet chain driven rear cam.

The cam support plate has four main functions.

Two ball bearings (H-D 8990 x 2) in 1999-early 2000 sit inside the cam-support-plate and support the outboard cam journals. INA #SCE148 (H-D 9198), roller needle bearings support the 1999-2006 inboard cam journals. They are located in the engine casing above and slightly to the left and right of the pinion bearing.

1. Secondly, the cam support plate feeds oil from the attached pump. The rotating pinion shaft drives the pump.
2. The cam-support-plate channels oil into the pinion shaft through the pinion bushing (25344-99). This distributes oil to the all-important bottom end bearings, crank pin, and the connecting rod races. In review, the end of the pinion shaft protrudes through the pinion bushing in the cam support plate and slightly beyond the plate. The pinion shaft protrusion enables the attached 17-tooth crank gear sprocket that drives the two silent timing chains via their related sprockets to rotate the twin cams and therefore operate the valve train. The support plate further directs pumped oil to other parts of the engine as a feeder system.

3. It also handles all load bearing parts that used to be the function of the timing cover in all predecessor Harley-Davidson engines. Its sole function other than noise dampening is to seal in oil and seal out dirt in conjunction with the timing cover gasket. The Twin Cam timing cover is just a cover. This eliminates one potential for oil leaks in conjunction with the very much-upgraded Twin Cam gaskets. This simple but radical departure from what has gone on before means the cover can now function efficiently as a sealing part instead of having to deal with moving parts supported by it.
4. Moving parts, especially if out of true or balance will try to work the Evo and predecessor Harley's supporting timing cover free of its hold-down screws. The gasket will be a poor last bastion against insidious oil weeping and finally leakage.
5. Lastly, the support plate also has other parts attached to and supported by it such as the timing chain tensioners, guide block, and of course, the oil pump.

The reason the Factory used ball bearings to support the outboard cam journal ends in the cam support plate is that they are quieter than other types of applicable bearings including roller bearings. Again, the Twin Cam evolved because noise reduction necessitated the move away from the noisier gears to the silent timing chain method.

Rear Cam Ball Bearing Breakdown

Tom, the oil pump damage in your engine is not the cause of your dilemma but the result of debris generated by the disintegrating rear cam-support plate ball bearing. Damage to the support plate and every other part in the timing chest is also a consequence of this, but again, is not the cause.

The rear cam-journal ball bearing (H-D 8990) design cannot handle the stresses imposed on it. I need to go over the cam drive mechanism again to explain stresses the bearings must endure.

The pinion shaft drives and rotates the rear cam via the primary timing chain.

1. The primary chain angles up and back (rear) from the pinion shaft on the outboard side of the cam support plate.
2. The shorter secondary timing chain on the inboard side of the cam support plate attaches to an integral cam sprocket on the rear cam. It connects horizontally to a similar integral sprocket on the front cam. Therefore, the pinion shaft rotates the rear cam via a longer upwards offset timing chain on the outboard side of the support plate while the rear cam connects to and drives the front cam via a shorter horizontal timing chain on the inboard side of the plate.

Negative Rear Cam Ball Bearing Stress

The rear cam has the weight and pressure of the valve train pushing down on its two offset cam lobes, has side-downward forces generated by the approximate 22 ½-degree angled primary silent timing chain and has a third force pulling to the side horizontally with the front cam.

The rear cam ball bearing cannot withstand these forces, particularly the angled one from the pinion shaft. It will begin to wear until the case hardened metal disintegrates. The vulnerable, relatively soft aluminum oil pump almost certainly is the second main component to begin to suffer. Debris then infects other parts like the hydraulic lifters causing them to collapse. Of course, the timing chain links begin to seize soon after this and vigorously destroy the spring-loaded tensioner pads.

If the engine is fortunate, the cam position sensor (32494-99) will be knocked out before too much injury occurs and will mercifully stop the engine.

Positive Front Cam Ball Bearing Stress

The front cam does not have any angular stress on it. It ably contends with the up-and-down forces of the valve train plus the sideways pulling of the secondary cam drive chain.

The ball bearing is designed for this but not the angular stress in combination with these.

Rear Cam Stress Requires a Roller Bearing

After correcting the HD-8990 ball bearing situation with the HD-8993 roller bearing, inner bearing race, and thrust washer kit supporting the rear cam journal in late 2000, mechanics soon realized and learned that there were two problems going on at once, not one.

We know the first, which required the bearing change to a roller design.

1. The second was rapidly wearing primary and secondary timing chain spring-loaded tensioner pads.

Before I go onto cam chain tensioner stress, let me clarify some bearing information.

The ball bearing by virtue of its design incorporates both an inner and outer race.

1. The ball bearing has inner and outer cages holding each round ball.
2. The roller bearing only has an outer race incorporated in its design.
3. The cylindrical shaped, roller bearings also have a cage that directs their rolling motion square with the mating cam journal.
4. The ball bearing is a complete unit that does not need side support or a separate inner race.
5. The roller bearing has side thrust issues from the cam side. Therefore a thrust washer is provided with the roller bearing kit that slides onto the rear outboard cam journal before race and roller bearing installation.
6. The race is press fit onto the rear outboard cam journal next.
7. The roller bearing now slides onto the race and abuts on its inboard side against the protective thrust washer.

Cam Chain Tensioner Stress

The tensioner pads, many times, will wear very quickly on their own causing debris entering the oil for circulation before removal by the most efficient filtering system to date.

Once again, as with a ball bearing used to support the outside rear-cam-journal instead of a more sensible roller bearing, Harley-Davidson used a quieter moving part than perhaps a more appropriate durable component for the stresses at hand. In my opinion, the engineers sometimes had imposed or self-imposed blinders on when designing the Twin Cam whose whole mantra rested upon two objectives.

The principal one was lessening internal engine part-component noise.

1. Quality and improvement to the H-D engine program was the second as the Factory geared up to move away from a niche market to become a mainstream recreational provider.
2. To do this, Harley-Davidson had to meet the Japanese Metric V-twin challenges of affordability and reliability while retaining exclusivity of *cool.*

The Timing Chain has Sharp Edges

The squared off silent timing chains result in a sharp edge; it is not sharp to the touch but the change in direction from the side plates to the inside or outside links is certainly very abrupt.

The one-inch long light brown tan colored tensioner pads that tension the two cam chains are ill equipped to deal with these sharp chain edges. The inboard secondary chain, although shorter still has severe wear issues. However, for reasons I will explain, pieces do not chip off or outright break as often on the secondary tensioner pad as happens with the primary tensioner pad.

The chain tensioner springs apply a pressure of 35lbs to 40lbs to the cam chains. The workshop manual advises to continue to use the tensioner shoe if there is still 50% of the original thickness left as H-D only advises replacing them "if worn to a depth that is equal to or greater than half the thickness of the shoe material". [7] They are only ⅛" thick when new. I do not think so! I replace them if there is any wear period since I do not trust pad durability one little bit.

H-D also feels that unacceptable wear has occurred if "there is any evidence of melting, burning, or cracking". [8] I am with the Factory on this one. I have seen them in every state of cracking and breakage.

In my experience, there is no correlation between mileage wear and deterioration of the pads. I have seen low mileage destruction as well as medium mileage destruction. Very rarely have I seen tensioner pads survive high mileage so don't hold your breath waiting for this possibility.

The Primary Timing Chain Induces Greater Pad Wear

The outboard primary-silent-chain is much longer. I feel the extra length encourages whipping actions that stress the primary tensioner pad more than occurs with the shorter secondary chain.

An extremely durable two-inch long black nylon chain guide (39965-99) sits to the right on the lead (pull), side of the 1999-2006 primary timing chain. This pad can easily survive until engine-rebuild time.

The 17-tooth primary-crank-sprocket attached to and driven by the rotating pinion shaft in essence pulls the chain keeping it taught. The non-adjustable fixed black nylon chain guide takes up some of the chain slack on this front lead side. The primary spring-loaded cam chain tensioner (39954-99) directly opposite the chain guide on the left tensions the chain. As I mentioned, there is a whipping action by the chain as slack creates and then suddenly draws taught.

The poor adjuster pad must deal with this and this is a reason that the engineers incorporated the chain guide on the longer primary cam chain. This thrashing action is the reason for the increased pad cracking and breakage on the outboard side of the support plate.

The Secondary Timing Chain Induces Less Pad Wear

Minimized whipping action results with the secondary timing chain on the inboard side of the support plate connecting the two cams because it does not have the same length and thus slack as the primary one. The pad can still wear at a rapid rate but chipping and cracking does not occur as much as with the outboard tensioner pad.

Skip Metz the respected H-D engineer told our *AIM* team that these pads would never wear out. [9] I am sure that he did not choose his words correctly as his enthusiasm about all the right aspects of the Twin cam engine became overwhelming in his pride of the accomplishment of designing the best, most reliable Harley engine ever.

The Primary Timing Chain Guide Pad is Long-lasting

Perhaps, I did not understand correctly and he might have been talking about the chain guide pad. The black nylon primary chain guide in our experience in working daily on Twin Cams since 1999 rarely wears out. In fact, we have never replaced one as of 2010. The pad discontinues with the new timing chain design in the 2006 Dynas and 2007 Twin Cams to present.

It is interesting that these two 1999 to 2006 tension pads, one spring-loaded and the other fixed are located on the same outboard primary chain but on opposite sides only inches apart and yet one wears out prematurely and the other is extremely reliable and durable. Maybe, white nylon should replace the tan tensioner-pad material amongst other necessary design changes. I say white nylon because this is what H-D began to use with the 2006 Dynas with much success thus far. Of course, the material change is complemented by a steady-as-she-goes hydraulic chain tensioner also with a rounded-edge chain.

The Primary Chaincase Drive Chain Pad Works Great

H-D Big Twin primary drive chains have had the same squared off abrupt edges as the 1999-2006 timing chains since their inception on the 1965 Panhead. White nylon adjusting pads from 1965 to year 2010 (39976-65B, 39976-01, 39929-06A) have adjusted the primary chains. Part numbers may differ but the concept and pad composition remains the same. Big Twin primary adjusters in use from 1965 to 2006 were not self-tensioning but manually adjusted during the maintenance schedule. The 2006 Dyna and all 2007-to-present Twin Cams have an automatic adjusting self-tensioning white nylon primary tensioner pad so we will see how this works out over time. As of 2011, it is working well.

Perhaps the tensioners should not have been spring loaded but hydraulically operated like the very successful Twin Cam 88B consistent pressure hydraulic operated balancer chain adjusters. Conceivably, the pulsating pressures that spring operated tensioners must deal with are the cause of failure. I wrote this last sentence in the first Twin Cam years. It turned out to be an accurate prediction and partial cure in conjunction with other changes.

Does Riding Style affect Pad Longevity?

On the other hand, it may be the different riding styles of Harley owners. I believe aggressive versus passive riding may dictate the seemingly inexplicable wear patterns of these 1999 to 2006 timing chain pads from one bike to the next. Harley redesigned all the cam chest-compartment parts in the 2006 Dyna and incorporated them in all the 2007-to-present Big Twins. The cam chain tensioners are no longer spring loaded but hydraulically operated and become very much more in charge.

The reliable primary timing chain guide discontinued because of the changes made it unnecessary, which is a major clue to the original problem. All of this is easy to hypothesize about and analyze for an analytical mind in hindsight, which has 20-20 vision. Looking forward can be blinding.

Engineers like the very talented Skip Metz and Koby Koblarz have their extensive experience and vast knowledge to design and create. They and their compatriot engineers have done a wonderful job relative to what has gone on in the past. However, when a problematic design situation gets past these people for whatever reasons the setback can have exponential effects.

I will address this unpredictable cam chain spring-loaded tensioner situation and its ongoing ramifications as well as aftermarket corrections throughout this volume and in Volume II: *Performancing the Twin Cam*. For example, an easy, reliable gear drive aftermarket fix eliminates the chains and tensioners. The repair upgrade takes much pressure off the bearings and tension no longer becomes an issue. Wearing tensioner pad problems cease because there is none. There are even bonuses:

1. Gear drive changes augment engine efficiency with by-product performance increases.
2. Engine efficiencies derive from higher lift, longer duration and increased overlap cams.
3. The relatively weak Twin Cam valve springs need replacement with higher seat-pressure springs to accommodate higher lift cams that ensure all cam lobe dictates are followed precisely.

Do Not use Stronger Valve Springs with 1999 to 2006 Cam Tensioners

Stronger valve springs may overwhelm the weaker spring-loaded tensioner springs, as they are both part of the valve train. These two types of springs have completely different agendas and functions.

If the valve springs dominate the tensioner springs then cam timing can vary with efficiency and performance robbing consequences. Therefore, we need a different timing chest system like gear driven cams from the aftermarket to eliminate the cam bearing and tensioner pad fiascoes.

The gear driven cams will dominate, as they should, directing the stronger valve springs necessary to control, and return valves to their respective seats necessary for productive cam changes. In short, there is delivery of more air into the combustion chamber. The much desired side effect is that the Twin Cam will become very much faster. I will explore this viable and desirable progression at length in Volume II: *Performancing the Twin Cam*.

H-D Corrected the Ball-Bearing Debacle Quickly

The serious ball bearing debacle was a teething problem corrected by the Factory almost immediately in about 22-months on late 2000 Twin Cams. Twenty-two months may not sound immediate but the process can only evolve so fast. Harley-Davidson corrected this problem as quickly as possible under the circumstances.

1. First, the problem must develop.
2. Then the engineers have to wait to see if the problem is widespread.
3. Next, thorough analysis of the situation is necessary to determine the cause.
4. Following is the next step of engineering a design change.
5. Lastly, the assembly line implements the design change.
6. While twenty-two months seem like a long time, it is not really when considering the stages and process necessary to reach a resolution especially with major components in the timing chest that dictate the accurate running of the four valve trains. An engine cannot run unless the valves open and close in a timely and coordinated fashion.

Quiet Damage

However, the wearing tensioner pads evolved into a confounding ongoing problem lasting seven years. Some engines would run 50,000 miles without suffering this affliction while others would only last a few thousand miles with no rhyme or reason to discern what was going on. Furthermore, it is a quiet damage until it causes other parts to malfunction. Other parts begin to breakdown before the timing chains themselves start to make noise.

Roller Bearings are Noisier than Ball Bearings

A roller bearing is able to withstand the three main forces imposed on the rear cam.

However, a roller bearing generates more noise than a quieter ball bearing. The whole purpose of Twin Cam development is to reduce noise. However, the Factory had already passed its initial EPA noise and emissions testing. I think the extra noise generated by the roller bearing is insignificant. I have a highly trained ear for mechanical noise. I never really notice it since there is always so much else going on.

The design of the front cam ball bearing is suitable for the less stress imposed on it. It too has the weight of the valve train on its two cam lobes. It also has a horizontal side force applied to it. The forces are up and down, twelve and six-o'clock, and sideways, nine and three-o'clock, so the forces are 90-degrees to each other. There are no problems associated with a ball bearing supporting the outboard cam journal of the front cam.

Cam Gear Drives do not need a Roller Bearing

Gear drives first developed by the venerable S&S Cycle, Inc. use ball bearings very successfully on both front and rear outboard cam journals. The stresses imposed by the gears driving the dual cams are very much suited to ball bearing support usage. The 22 ½ degree-angular rear cam timing chain force eliminates with the constant meshing gears. All forces become 90-degrees to each other.

Rear Cam Journal Bearings

S&S always supplies Torrington B148 needle roller bearings to replace the inboard INA #SCE148 (H-D 9198) 1999 to 2006 rear cam journal-support bearings for reasons I will discuss later.

Conclusion to Tom's Cam Dilemma

Tom, the aftermarket cams you used are of the highest quality and design. They are probably not the cause of your situation. You say the shop that installed them is very competent so it is unlikely they are at fault.

Harley-Davidson does not know the quality of the installing mechanic or the quality of the installation nor can they accept blame for an aftermarket part's demise.

- However, we cannot eliminate these factors entirely since who can say at this point if the installed cams did not have a problem, rare, as it would be with these fine products.
- Every mechanic has a bad day, not that should affect quality, but we cannot one hundred percent eliminate installation problems as the cause.

When working on Twin Cam engines there are a host of new tools designed for this purpose. It is crucial to use the proper tools, the correct nut and bolt torques and the correct torque sequences. It is not impossible but certainly very difficult to do quality work on this new engine without them. All the TC88 specialty tools are available from Kent Moore a separate company from Harley-Davidson.

As an educated guess, the problem has nothing to do with the installation of performance cams in your engine or the mechanic that installed them. Harley-Davidson is not warranting these situations with aftermarket cams. I would not be predisposed to guarantee similar situations either if in their place.

H-D engineers know that they have a problem with their stock components. They also know the cause of the failures. They do not know if they are at fault in this particular situation because of the unknowns, we have discussed.

Tom, the dealer blamed it on the cams and made you pay for the upgraded bearing support plate, bearings, oil pump etc. when they knew the cause was very likely the stock parts that caused the failure. The rumor mill has been churning for months now. Mysterious engine failures have occurred precipitated by catastrophic damage in the timing chest on the lower right side of the engine. Tales of spun cam journal end bearings, failed cam support plates, badly worn and disintegrating cam chain tensioners, blown oil pumps, and hydraulic lifters polluted with fine metal shavings abound.

The Engine Build Date Determines the Rear Cam Bearing Defect

First, let's see whom this bearing failure affects and who it does not. The *build date* of your engine, from Milwaukee's massive Pilgrim Rd. plant, and *not* the assembly date, which is done in the York Pennsylvania plant, of the motorcycle is the important piece of information to determine if your bike is affected or not.

Whether the inappropriate rear cam ball bearing made by Nachi (6004 C3) who was the vendor for Harley-Davidson, which identifies this bearing as HD-8990 is installed in the rear of the cam support plate or the new improved roller bearing (H-D 8984) has replaced this ball bearing is the information we are after. You or your dealer can phone the Factory with the two engine serial numbers required to identify the problem engines.

The first is the registration vehicle-identification number, (VIN), off the left side engine casing at the base of the cylinders.

1. The second is the motor number off the bottom of the right engine case.
2. If the engine build is before December 14, 1999, then you have the problem rear cam journal ball bearing HD-8990.
3. On and after December 14, 1999, the new improved roller bearing (H-D 8984) with the new cam support plate (25267-99B) will have been installed in your engine.

H-D Manufactures in Half-years

You may have a bike manufactured weeks or possibly months after this date even with an earlier build engine. In general, any Harley manufactured after July-August of 1999 will be registered and sold as a year 2000 model. The next year production begins anywhere from four to five months in the previous year. Each manufacturing year has an early and late production. For example; in general, the early 2000 models will have fewer changes than the later 2000 manufactured bikes. H-D introduces many mechanical changes half way through the year to correct problems, institute improvements or for a variety of other reasons. Therefore, early

2000 bikes will mechanically mimic late 1999 models while late 2000 bikes will be more similar to early 2001 models.

Roller Bearing will fit over both 1999 Key and 2000 Spline Journals

The reader will know from previously read material that the rear cam, which drives the front cam via the silent cam chain, has a keyway as part of the rear cam sprocket on 1999 models and multiple splines on the 2000 engines.

This difference will not affect the installation of the new roller bearing replacing the ball bearing on the rear cam journal. I mention this because the camshaft end roller bearing must fit past and behind the keyway slot or splines whichever the case may be.

Replace 1999 Rear Cam Sprockets

1. If your 1999 to early-2000 bike is fitted with the keyway slot on the rear cam, I advise to replace the OEM stock sprocket with the upgraded Andrews rear cam sprocket (288010) with separate Woodruff key.
2. Also, change the defective early cam gear bolt (H-D 898) and washer (H-D 6278) defective on the 1999's with the upgraded bolt and washer kit (25533-99A) that contains two of each. I haven't mentioned this before because it was not an issue but the 17-tooth pinion shaft-driven cam primary drive sprocket (25609-99) is also held to the pinion shaft by this same bolt and washer. Again different forces and stresses will make the difference between a successful fastener and one that breaks just like the cam support bearing situation exemplifies.

Installation is very specific so read the instructions carefully. Part of the fix is a slightly different installation procedure. Follow the instructions listed earlier in this chapter.

Riding should be Worry-Free

I as you am irritated that Harley has not launched a recall. I fear Harley will only fix this problem at their expense if your engine blows up and you have to be towed in from who knows where with all the inconvenience that will entail. Who wants to wait until their engine blows? Who wants to ride around constantly worried that their engine may or may not self-destruct?

There are obvious safety issues also. The rider may be in a situation that relies on power when the power may suddenly stop.

Courtesy Goodwill Warranty

If you are past your warranty period and have this failure, Harley *may* pay through a courtesy goodwill warranty. H-D has a good record of this in the past if you are the original owner.

So what happens to the poor sap that buys a used Harley that is out of the original warranty? I think we know the likely result. However, the squeaky wheel gets the grease. If paying for this defect repair before a problem arises, keep your receipts and the replaced parts in case there is a recall sometime in the future.

As a side comment, I suspect that my use of synthetic oil in my early 1999 FLTR is prolonging the time before any problem that may occur.

Reading the Oil Filter for Engine Damage

Earlier, I discussed that there really is not much noise until parts are ready to destruct.

Here is what I do with every oil change since I am looking for this problem. I also follow this procedure with suspect customer bikes. Any other time if not anticipating any untoward situations developing, I may do this every second oil change.

Have your mechanic examine the best filter used to date on any Harley, the 10-micron synthetic media oil filter after taking it off. Cut the metal away and extend the fibrous cloth. The pre-TC88 30-micron Evo filters have a paper element that extends easier.

Put the material up against the sun and voila¢. Any damage will be there for all to see. Currently I have fine metal specks throughout the filter cloth…about what I would expect with such a good filtering system.

There is one thing to be aware of. The oil pump pulls oil from the oil tank into the cam support plate. The oil is then routed through the crankcase to the filter mounted on the front of the right side of the engine. So, although the oil is filtered before it goes into the majority of the engine, some contaminated oil can go through part of the engine although this has demonstrated not to be a big deal.

1. If the bearing is wearing, there will be lots of shiny particulate encased in the filter folds.
2. If the tensioner pad is wearing too much, there will be a brown, non-metallic sampling caught in the filter also.

Fixing the Rear Cam Bearing Problem at the Factory

Originally back in 1999 when the spun rear cam-support plate ball bearing was becoming a problem, the engineers felt that maybe there was too tight a fit for the bearing in the cam support plate. The Factory increased the ball bearing's hole-size opening in the support plate and eliminated the press fit instituting a loose fit. Now, the bearings would literally fall out of the plate via gravity during disassembly. Thus, this will eliminate any theoretical binding problem.

The engineers also felt that maybe there was misapplication of proper torques and torque sequences. This is a very legitimate concern.

The Twin Cam Does not Forgive

In the old Shovelhead days, the engines were very forgiving of pseudo-mechanic mistakes. This changed with the Evos, which were much less forgiving of mechanic error. The most precise of all H-D engines to date, the TC88 has the potential to crucify mechanic slip-ups with catastrophic damage.

However, the problem still occurred while using the rear cam-support ball bearing fitted loosely in the cam support plate. It turns out that the cam support plate, wrongly accused as the main suspect, was largely innocent of any mechanical transgressions. The engineers acquiesced and the Factory started to use a roller bearing for the rear cam in the cam support plate, which of course, supports the outboard rear cam journal closest to the cam cover. They rightfully left the front cam-journal ball bearing as is.

The final 1999 to 2006 cam support plate is third generation. The switch to a rear roller bearing from the ball bearing has become the fix.

1999 and early 2000 Cam Bearing Repair Kit Parts List

Description	Part No
EFI Models: Complete Kit	24984-99
Carb. Models: Complete Kit	24985-99

Repair Kit Contents

Qty.	Part Number	Description
1	25297-99	Rear EFI Camshaft
1	25296-99	Front EFI Camshaft
OR		
1	25544-99	Rear Carbureted Camshaft
1	25534-99	Front Carbureted Camshaft
PLUS		
2	9198	Cam Needle Bearing
1	25267-99B	Cam Support Plate
1	25716-99	Cam Sprocket
1	25938-99	Cam Sprocket Spacer Kit
1	25609-99	Crank Sprocket
1	25619-99	Primary Cam Chain
1	25607-99	Secondary Cam Chain
1	25533-99A	Cam Gear Retention Kit
1	26035-99A	Oil Pump Assembly
2	11301	Oil Pump O-Ring
1	11286	Oil Pump O-Ring
5	11293	Oil Pump/Push Rod O-Ring
4	11132	Push Rod Cover O-Ring
4	11145	Push Rod Cover O-Ring
4	18538-99A	Hydraulic Lifter
2	18635-99	Lifter Cover Gasket
2	11270	Breather O-Ring
2	26858-99	Umbrella Valve
2	17592-99	Breather Baffle Gasket
2	17591-99	Breather Cover Gasket
2	17386-99	Rocker Cover Gasket
1	25244-99	Cam Cover Gasket
1	26077-99	FLT Oil Pan Gasket
1	26072-99	Dyna Oil Pan Gasket

Fixing Outer Cam Bearing Damage

There is a lot more to this than the mere replacement of the cam support plate (#25267-99B), fitted with the new style rear cam roller bearing assembly (H-D 8983).

Unless the problem is caught in the initial stages, the shrapnel and the devious finely ground up case hardened metal from the ball bearings and cam journal ends will certainly demolish the fragile aluminum oil pump housing and the cam support plate. No oil equals zero engine lubrication. The destruction continues. Finally, the engine stops because cam timing goes so far out of whack. The fine metal particulate debris will inundate everything in the timing compartment.

H-D Service Bulletin M-1100 issued on July 10, 2000 relates to the Factory's fixing the problem after the blowup. It informs repair facilities that cam bearing repair kits are available to fix rear cam bearing problems.

There is one for carbureted, (24985-99), TC88And B models.

1. The other is also for A and B models that are fuel injected, (24984-99).

The main divergence between the two kits is that different specification cams are used depending on whether the bike is carbureted or injected.

At Heavy Duty Cycles we try to interdict impending destruction before Armageddon occurs so quite often we only have to replace a few parts such as the support plate, bearings and the chain adjusters, which also have their own separate wear agenda.

Is Bearing Debris Damage Confined?

Please see the preceding chart for a comprehensive list of the replacement parts in the H-D repair kit(s) for TC88And TC88B. These H-D repair kits are extensive in that the Motor Company has waited for the most possible destruction before reacting. This is why the kits include timing chains, timing chain sprockets, an oil pump, four hydraulic lifters and a host of lesser but equally important parts. H-D also wisely and importantly recommends that the oil pan under the transmission also be thoroughly cleaned when there has been engine damage.

However, for my peace of mind, I have decided to replace the timing chain apparatus with a gear driven cam system first made by S&S Cycle, Inc. followed by Andrews Products, Wood Carbs, and then Crane Cams on my future personal Twin Cams. *Harley says that any damage will be contained and confined to the cam compartment and the return oil system.* Knowing the design of the TC88's, I can theoretically agree with this statement and am somewhat comfortable with it. As a footnote, Crane Cams succumbed to the recession in 2009.

Nevertheless, I have been around Harley engines a long time and although an inanimate object, many times the beast does seem to develop a mind of its own. By this, I mean that I think I will wait a year or two before I totally endorse this damage containment to the cam compartment, although I have no mechanical reason at first thought to be uncomfortable. However, I have a nagging doubt since something is not sitting right in my gut.

If the reader is interested in how the switch over from ball to roller bearing is accomplished, begin at page 3-84 of the 2000 FLT Models Service Manual. The information is applicable whether you ride a Dyna, FLT, or Softail model. In fact any 2000 or 2001 Twin Cam manual will have much information.

However, the cleanup is different for the Softail. Service Bulletin M-1100, (Cam Bearing Repair Kits), addresses this also.

There are some important points to mention as timing the drive gears and cam drive sprockets are crucial.

The cam journal outboard end sprockets cast into and part of the actual cams that the secondary cam chain fits onto have a timing mark punched into the outside (outboard) face of each cam journal end. It is necessary for the punch mark on each face to align with the punch mark on the opposing gear face. These sprockets time to each other in order that the valves open and close at the proper times.

1. These marks indicate and correctly align the location of the two offset and egg-shaped cam lobes per cam. This valve timing is important.
    a) The intake valve in each head begins to open on the last part of the exhaust stroke just as the mating exhaust valve is closing.
    b) The intake closes after the compression stroke begins while the exhaust valve remains closed.
    c) The exhaust valve begins to open while the power stroke is still occurring and on it goes; so we see that there is a lot of complicated stuff going on here.
    d) Furthermore, each cylinder has a different stroke going on than its mating cylinder. For example, while the compression stroke is happening in one cylinder, the other is experiencing its exhaust stroke.
    e) Now, add to this the timing of when the spark plugs ignite relative to piston position and valve opening and closing and we have what seems at first glance a logistical nightmare.
2. The cam lobes time to each other via the cam timing marks, while the primary timing chain outboard sprockets time to each other and the pinion shaft attached to the flywheels, which coincidentally direct piston travel, speed, and location.
3. Let me go back to the cam sprocket timing marks, which must align with each other. It is nice that the timing marks are conveniently located on the sprocket outer faces. However, these outer faces face the cam support plate and become invisible when installed. Therefore, there are also timing marks in the same crucial timing locations on the outside end of the outboard cam journal adjuncts that extend through the cam support plate and mount the primary timing chain gears.
4. Another wrinkle evolves for the thinking reader in that the secondary chain integral cam sprockets do not mesh but locate a few inches from each other on a horizontal plane. Enter the steel-edged ruler that the mechanic lays across the end faces of the primary sprocket adjunct faces to ensure the timing marks align when the cams are installed into the cam support plate.

Before the reader throws his hands in the air, sectionalize and view this stuff separately, it becomes logical and easily understandable before throwing it all together again as I will fully explain in Volume VIII: *How it all Works.*

1. In review, the cam lobes dictate when the valves open and close and have a tight, unforgiving relationship with when ignition timing occurs. The position of the cam lobes is nothing short of being critical to the engine even starting, never mind running.
2. Chain orientation is also crucial. The chain will have wear patterns for travel in one direction only. Putting a used but 100% serviceable chain on backwards to what it was is a no-no.
3. During disassembly, mark the inboard (visible), side of the secondary cam chain with a colored marker.
4. During assembly, ensure the side of the cam chain with the colored mark is facing opposite the cam support plate. Obviously you saw it when marking it. If you can see the mark after reinstallation, then the chain is oriented in the correct direction.
5. When re-installing the camshafts into the cam support plate, align the punch marks on the sprocket faces with each other. Of course, when the cams install into the support plate bearings, seeing these timing marks anymore is impossible as the gear faces buttress up close to the inboard side of the cam support plate. The secondary

cam chain now fitted over the sprockets and tensioned by the secondary cam tensioner further obscures them.

6. Therefore, during the dual cam installation into the cam support plate, Harley wisely advises taking a colored marker and drawing a mark on the rear inboard side of the cast-in cam sprockets teeth so that the two timing marks are visible and aligned with each other as the cams press into place. Of course, I guess they give this advice because they probably forgot to put a punch mark there also.
7. I should not have to say this but I suppose the uninitiated or the daydreamers might mix up the front and rear cams and their respective locations. Final assembly of the outboard cam support-plate parts will become impossible. The front cam's outboard cam journal end has a circlip indent so the circlip (H-D 11494) can hold the cam in the ball bearing. Furthermore, the rear cam outboard cam journal end extends through the upgraded roller bearing with the keyway configuration (1999), or as a splined protrusion (2000-present), is readily evident to anyone paying the least bit of attention.
8. The final cam-to-cam timing check is done after installation in the cam support plate by rotating the cams in the support plate until the end timing marks align. This is checked for accuracy with the steel straightedge or ruler. Earlier cams had a punch mark depression while later cams have an actual line timing mark imprinted on the outboard cam ends. The cam timing punch marks or lines as the case may be should already align diametrically across from each other. If not, at this point rotating the cams until they are allied is no longer possible as alignment is fixed out-of-time.
9. If out-of-time remove the cams and start over. Once again, lay a straight edge across the outer cam-end faces to verify and ensure these marks are in horizontal alignment.
10. Install the cam support plate and torque it down to 90 in-lbs to 120 in-lbs (10.2Nm to 13.6 Nm), sequentially in a cross pattern in the timing chest cavity. By the way, do not misread the torque value, like so many do. The value is in inch-pounds not foot-pounds.
11. Then install the primary crank and secondary rear cam-drive gears and their timing chain.
12. During disassembly, stain or mark the primary cam chain on the outside with a color marker to ensure its directional rotation integrity maintains during reassembly.
13. The 17-tooth pinion crank sprocket has a flat on its inside diameter that aligns and fits over a flat on the end of the pinion shaft. It also has a timing punch mark on a male tooth that extends outward.
14. The 34-tooth rear cam secondary drive gear has a similar punch mark but on an inward female tooth. On 1999 models, this gear fits via a keyway slot onto the cam journal-end extension. Late 2000 to present models utilize the superior multi-spline attachment method.
15. Some jockeying of the two sprockets with the chain on them is required so these two timing marks wind up diametrically opposed to each other. The two gears do not mesh with each other but the timing marks will be about seven-eighths of an inch from each other when aligned.
16. Lay a straightedge flat across the centers of the pinion shaft end and the rear cam-journal end. If correct alignment of the primary timing gears alignment marks occurs, they will align along this same axis of 22 ½^0 offset.

I have only mostly mentioned timing issues during the assembly comments. Consult a workshop manual for the rest of the installation procedures. The Twin Cam is not a forgiving engine if not following torque values, specifications, and instructions.

Identifying Carbureted and EFI Camshafts

There will be an A or B stamped on the outboard cam journal ends. These do not stand for an Alpha TC88A or Beta TC88B engine if installing new stock H-D cams. In this case, A stands for a carbureted engine while the B indicates the cams are for a fuel-injected engine.

What causes the Engine to Stop?

If the rear cam bearing begins its destructive disintegration, hard metallic debris will begin oil pump Armageddon. Before the lack of lubrication can cause a seizure, the engine will in most cases shut down. The cam timing going out of whack will usually cause this. If that does not do it then destruction of the magnetic pickup sensor will. The cam position sensor…part number 32496-99 upgraded to 32793-00 in year 2000…located by the rear cam outboard drive 34-tooth sprocket will cause the engine to stop running because the cam and the Hall effect ridge on the 34-tooth sprocket front face will be all over the place instead of rotating precisely in position. Therefore the cam timing as well as the cam position sensor readings will be constantly changing well beyond the specification boundaries.

Cam Position Sensor (Impulse Generator)

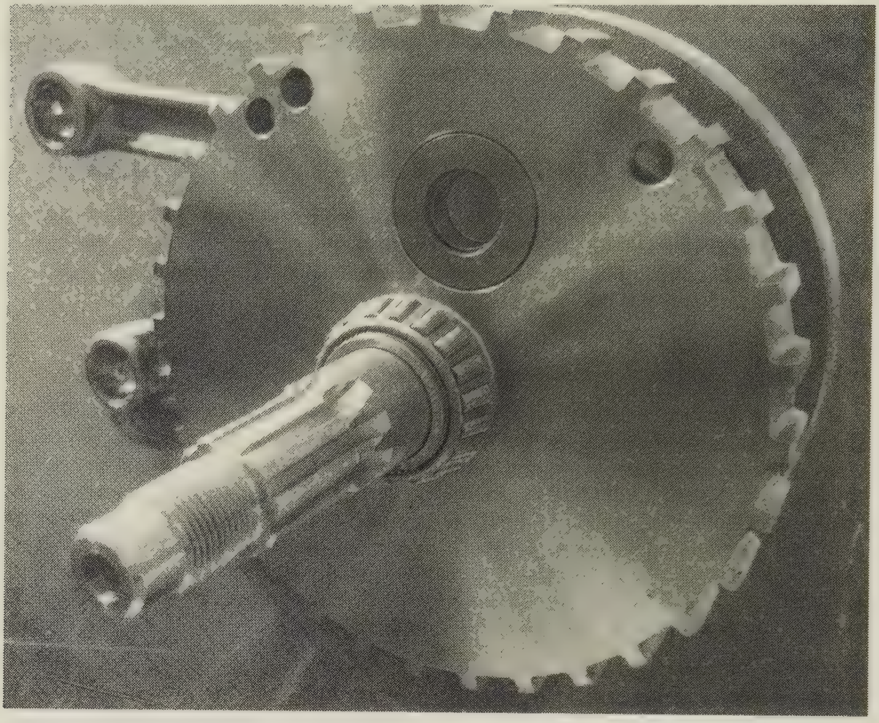
The sensor is basically a magnet known in mechanical theoretical lingo as an *impulse generator*. This sensor measures where a circular quarter-inch high ridge and almost half as wide called a Hall effect rotor is located on the outboard side of the rear cam drive sprocket. The rotor (ridge) also known as a trigger wheel is near the outside diameter of the sprocket. The rotor ridge goes a little more than half way around the sprocket surface.

1. The cam position sensor and its electrical wiring sits in a hole behind the timing plate of the timing chest cover and measures through magnetic pickup where rotationally this ridge's location is; when it begins, and when it ends.
2. This is called a *Hall effect transistorized ignition*, more commonly known as part of an electronic ignition system. The magnet generates a pulse of electrical current instigated by the ridged rotor.
3. This pulse is used to trigger the electronic control module, which signals the ignition to fire the spark plugs.

As the rear cam ball bearing begins to destruct, the cam journal will not run concentrically but will be allowed to diverge and move depending on the varying valve train weight and the pull of both timing chains. The attached 34-tooth sprocket with the Hall effect ridge will extrapolate this movement and will literally be weaving around. The magnet will impact with the trigger wheel ridge, be knocked out of service thereby shutting the ignition down.

If given a choice, we would want the cam sensor to be affected as soon as possible with this scenario. The alternative is further wear and destruction of other timing chest components like the oil pump and hydraulic lifters.

For an explanation of Hall effect please see sections; *V-Fire II Ignition Hall effect Trigger Rotor* and *V-Fire III Ignition Hall effect Trigger Rotor* in Chapter IX, *Synchronizing Ignitions and Fuel Delivery*. Hall effect devices have been in use since their discovery in 1879. They still effectively fulfill necessary functions in brand new Twin Cam motorcycles.



1999-2002 Twin Cam Flywheels: Sprocket Shaft Side

Pictured is a set of 1999-2002 flywheels also known as the crank or the flywheel assembly. The left side flywheel also known as the power side or the sprocket shaft flywheel has thirty equidistant ⅝"-wide indent notches about ¼" deep cut into its outer rim. The peaks are about a ¼"-wide. Then there is one notch (7 o'clock position) cut the same depth but about 2 ⅛"-wide that indicates the pistons TDC to complete the whole circumference of the flywheel. A crankshaft position (CKP) sensor, which is basically a magnet, sits in the front engine casing. The magnetic pickup of the sensor relays pulses generated by the notches rotating past it to the electronic control module, which will consult the spark map matrix in conjunction with other sensor information to determine which cell will spark the ignition. This sensor can read where the pistons are in the cylinders and the position of the cam lobes as well as when the valves are opening and closing because of the sequential series of key parts throughout the engine that time to each other. The sprocket shaft is cast with the left-side flywheel and integral with it. The 1999 to 2006 sprocket shaft has ten ⅛" splines; all shafts have the same number and configuration of splines since 1956. This compares to 2007-to-present where the splines are much thinner and increase to twenty-four splines. Therefore, engine sprockets, their compensator springs, and alternator rotors that sit on the sprocket shaft splines are not interchangeable from 2007 to earlier engines or vice versa. The sprocket-shaft-tapered Timken bearing pressed onto the shaft fits into a race pressed into the engine case. There is another tapered bearing and case race pressed on after the left case assembles over the sprocket shaft. A spacer between the two bearings determines the end spacing of the flywheel assembly, which allows the flywheels to turn freely but not slide back and forth in the engine casings. Circa 2003, the Factory replaced this excellent and durable Timken bearing kit (H-D 9028) setup used since 1969 with a similar Timken kit going back to 1956 with a roller bearing (24604-00C) like that used on the Twin Cam pinion shaft. One end of the pressed in hollow crank pin is visible with its press fit end cap used to create a cooling oil reservoir for the bottom end crank pin, bearings and con rod races. The drill holes removing weight in specific areas are for dynamic (moving) balancing purposes to combat vibration. The connecting rod small ends have wrist pin bushings pressed into them. Wrist pins attach the pistons to their respective con rods.

The Crank Position Sensor replaces the Cam Position Sensor

The cam position sensor is used in 1999 to 2001 Twin Cams and complements the crank position sensor, which measures flywheel rotational location. In 2002 the cam position sensor was eliminated. The crank position sensor that it previously complemented replaces it.

This crank position sensor reads location and speed of the pistons in their cylinders plus the positioning of the 4-cam lobes, as well as when the valves are opening and closing because the sequential series of key parts that attach to and are timed to each other.

The flywheel components are fixed and do not move in relation to each other except as designed.

1. The right flywheel pinion shaft end-flat that the 17-tooth crank drive gear sits on times to the flywheel rotation.
2. The 17-tooth crank drive gear is timed to the 34-tooth rear cam drive sprocket.
3. The Hall effect trigger ridge on the outboard face (front) of this rear cam drive sprocket is therefore timed to flywheel position. Of course, this is only used from 1999 to 2001.
4. The rear cam times to the rear cam drive sprocket.
5. The front cylinder cam times to the rear cylinder cam.
6. The cam lobes are fixed and never change position. Therefore, the crank position sensor knows where all these parts are in relation to each other, including the valve train with opening and closing valves.
7. Thus the magnetic pickup of the crank position sensor knows where the flywheel assembly is in its rotation, which indicates where the pistons are in their respective cylinder bores.

The flywheel location crank sensor will instruct the electronic control module, where all of the internal motor parts are in their movements and rotations.

The crank position sensor (32497-99, 32798-00, 32707-01, 32707-01A, 32707-01B, 32707-01C) is once again a magnet clamped down at the left-side front of the engine casings. Part numbers for this sensor vary over the years primarily because of diverse locations of the electronic control modules so wiring length etc. will be different.

The left, or power side, flywheel has thirty equidistant ⅜"-wide indent notches about ¼" a deep cut into its outer rim. The peaks are about a ¼"-wide.

1. Then there is one notch about 2 ⅛"-wide to complete the whole circumference of the flywheel, which indicates piston TDC. Both pistons rise and descend in tandem so TDC is the same for both although they are on opposite strokes of the 4-stroke cycle.
2. The magnetic pickup of the sensor relays pulses generated by the notches rotating past it to the electronic control module, which will allow the ECM to read the spark map matrix in conjunction with other sensor information that will spark the ignition.

Bearing Damage Cleanup

If the damage to your Twin Cam and subsequent repair occurred before Harley-Davidson issued its Service Bulletin on July 10, 2000 (M-1100 Cam Bearing Repair Kits) look at your repair work order to see if an FLT oil pan gasket (26077-99) or the Dyna gasket (26072-99) as the case may be, is listed and therefore changed.

If not, we have to get cleaning.

With Softails and all other models with gravity-fed oil tanks found on all Sportsters, earlier FLT models, Shovelheads, etc. there is a cleaning procedure whenever doing engine work. This involves flushing the oil tank and oil lines to clean out all harmful filings and debris. If there has been extensive engine damage, I always replace the flexible oil lines after thoroughly flushing the oil tank.

Let's compare Evolution FLT oil pans with their TC88 counterparts. The oil in the Evo pan located under the transmission has a feed and return at the front, which means that the same oil gets used over and over again while fresh, cooler un-circulated oil is allowed to hang around at the back. The TC88 rubbermount FLT models eliminate this situation by having a baffle plate in the oil pan that ensures the returning oil follows a tortuous path throughout, making sure it is totally circulated. This allows more efficient cooling and the use of all the oil all the time. It also allows total dispersion of contaminants. In 2009, H-D further refines and improves FLT and Dyna oil reservoir baffling and oil recirculation.

The oil pan must be removed in order to thoroughly clean out debris from the baffle plate. Now it is a real hassle to remove the oil pan on the TC88 FLT models because the rear wheel has to be removed first. So many novice wrenches learn cleanliness is next to godliness the hard way. Shortcuts taken because of laziness or a lack of knowledge will allow fine hardened metal particles back into the engine since the filter will not catch everything or may become overwhelmed with debris and plug oil flow to wreak destruction one more time.

Sometimes a fix is an educated evolutionary process of trial and error. Consult your manual to learn the proper way to do this for your year and model.

Timing Compartment Debris

An ongoing concern with the Twin Cam engine increasingly focuses on damage in the timing compartment and its associated parts on years 1999 to 2006. Newer 2006 Dyna and all 2007-to-present Twin Cams are not exhibiting problems as of 2010 but while we are well on our way we are not yet out of the woods yet on this one.

Stevie, my head wrench for twenty-nine years, called me into our service department in 2000 to look at a set of pistons he just removed from a Twin Cam. Fine shiny metal particulate impregnated the piston walls. Upon further investigation, we concluded that this foreign metal debris could only have come from the *separated* timing compartment.

As I have discussed previously, Harley-Davidson was pretty much forced to abandon gear-driven engine parts because of noise emissions dictates by the U.S. government. This meant the demise of the gear-driven, single-cam Evo valve train and the progression to a quieter timing chain-driven dual cam TC88 set-up in 1999.

Two cams were required to keep the basic shape of the V-twin that we all love.

I have written extensively on 1999 and early 2000 Twin Cams with rear cam-bearing problems. This was supposedly corrected in late 2000 by upgrading the cam support plate and replacing the rear cam ball bearing with a roller bearing. I think Harley really dragged its feet on this problem in the beginning with owners of the ball bearing-affected bikes. The new cam plate and rear roller cam bearing corrected a large percentage of bikes suffering from this particular predicament.

However, we see evidence of continuing problems all the time in our service department even with the late-2000 and up rear cam roller-bearing engines. For example, I highly recommend changing the inside cam journal bearings in the engine case every time the timing chest is opened up. We at Heavy Duty Cycles (www.heavydutycycles.com) replace the stock INA SCE148 (H-D 9198) bearings with Torrington B148s in *our entire* 1999 to 2006 Twin

Cam engine work. S&S Cycle, Inc. and Crane Cams also supply or recommend these bearings for their gear drive systems that are used to replace the timing chains.

Timing Chest Class Action Lawsuit

Harley-Davidson defended itself against a consumer class action case regarding TC88 timing chest problems. One of the class action's contact lawyers is Jonathon D. Selbin of Lieff, Cabraser, Heimann & Bernstein, LLP; 780 Third Avenue, 48th Floor, New York, NY, 10017-2024 USA.

- H-D won against this class action suit in lower court.
- On Jan. 14, 2003, the Wisconsin Court of Appeals overturned Harley-Davidson's lower court victory and ruled in favor of the consumer.
- The Wisconsin Supreme Court accepted the appellate case on June 12, 2003 for review.
- Final resolution occurred July 12, 2007, when the Wisconsin Supreme Court ruled narrowly in favor of Harley-Davidson by four to three.
- While the consumer class action case was defeated, the statutes of limitation on individual claims against Harley-Davidson over this matter relating to the alleged defect in the TC88 engine have been *tolled*. This is a legal term for put on hold.
- The statutes of limitation for individual claims began running again as of July 12, 2007.

Harley-Davidson 5-Year/50,000 Mile Warranty

In January 2001 a proactive customer of mine who complained loudly and incessantly received a letter from Harley-Davidson. It stated in part that if a problem occurs in 1999 and early 2000 Twin Cams that the Factory has instituted a five-year/fifty-thousand-mile warranty on the rear cam bearing. The customer requires no warranty registration.

The warranty will follow with the new owner(s) if the bike sells. This was a welcome bit of news…better late than never…except for one thing. The engine compartment had to self-destruct because of the problem before the warranty would be instituted. There would be no warranty for those who wanted their timing compartments checked to see if there was a problem in the making.

Now there were probably tens of thousands of owners of the early year Twin Cams wondering if and when a severe mechanical problem was going to develop as they rode down the highway. As near as I can figure, there would have been up to a hundred thousand Twin Cams affected by this potential malaise.

As any rider knows, having to wonder or worry about a mechanical problem ruins the relaxing quality of riding in the first place, never mind where it might happen. Murphy's Law states that breakdowns never happen in front of your favorite repair facility. So these hapless riders would have to wait and see what was going to happen, if anything would happen at all.

Many riders like me just went ahead and corrected the problem on their own dime in order to have peace of mind. I did this on two 1999 FLTR Road Glides that I have personally owned.

1. In both my TC88 Road Glides I found varying degrees of damage to the cam support plate rear ball bearing.
2. There was inappropriate wear on both INA cam bearings (H-D 9198) that support the two cams inside journal ends located in the engine case.

3. Furthermore, the timing chain adjusters were badly worn on one bike and moderately worn in the other.
4. Both FLTR's had less than 5,000 miles when inspected. We are now finding:
    a) Damaged INA inner cam bearings (H-D 9198).
    b) Worn timing chain adjusters (39954-99 primary; 39964-99 secondary).
    c) Cam lobe damage on all year Twin Cams.
    d) Since we do a lot of performance work, we take apart many engines that appear to be running well with no outward symptoms of wear or impending problems. Therefore, we accidentally discover a lot of this malaise that we were not initially looking for.

Any competent mechanic thoroughly cleans and inspects all disassembled parts for wear and specification tolerance limits as listed in the H-D workshop manuals. Of course, we now check the timing case components religiously and rigorously.

We also get to see wear patterns that may predicate and lead to future concerns.

TC88 Cam Wear

In our experience at Heavy Duty we see a lot of earlier cams showing premature wear. This is indicated by case hardening on the cam lobes showing evidence of wear with initial *spalling*. Spalling is technically a fine flaking process. The hardened surfaces show very fine pock marking with both pinpoint and watermarking descriptive shapes.

On some later Twin Cams we are still seeing examples of cam wear but also a disturbing manufacturing boondoggle. The first set that we pulled out of a Twin Cam seemed to be a manufacturing defect where the tooling malfunctioned or a step in the cam lobe grinding process was inadvertently skipped. The cam lobes exhibited a stepping contour of flat spots instead of a round, smooth contour for the lifter roller to glide over. Now we have seen it more times.

An engineer has advised me that he feels the stepped cam surface characteristic is the result of the cam grinding machines either inadvertently being turned up too fast or a deliberate attempt to boost production beyond maximum capacity of the machines. Harley-Davidson rigorously looks for problems like these in the production line, so seeing this particular problem was a surprise.

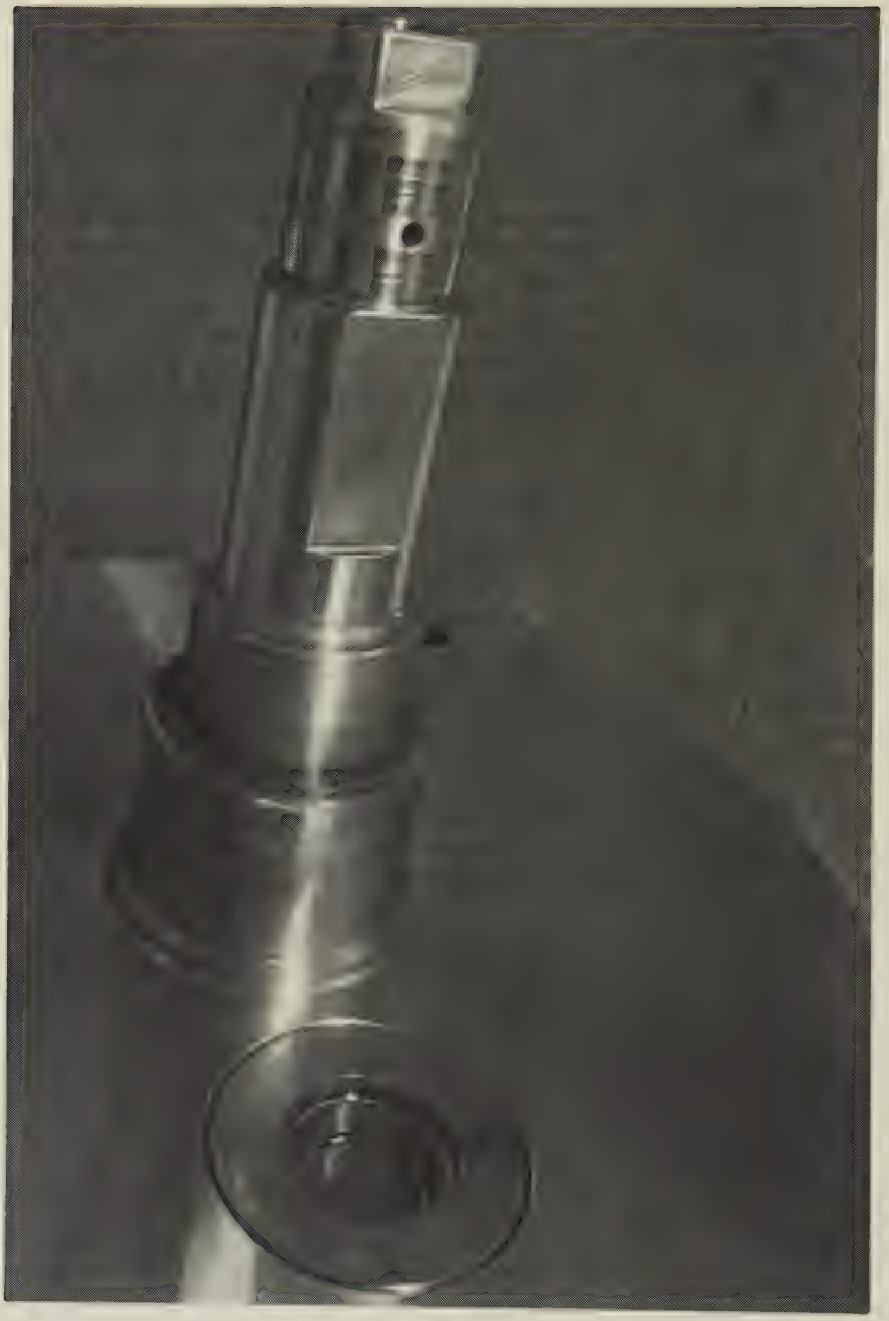
Certainly, Harley has ramped up production considerably in the last few years to 289,000 units in 2003. This is a long way from the 50,000 unit levels in the 1980's.

Is Metal Debris Confined?

What happens to all this metal in the timing chest once a destructive breakdown has occurred for whatever reason(s)? As I relayed earlier in Harley-Davidson's Service Bulletin M-1097 titled *Cam Bearing Repair Kits*, the Factory feels that debris will be confined to the timing compartment and the return oil system.

I agree that the majority of contaminants will indeed be confined to this area, especially large pieces that liquid oil or displacing oily mist cannot pick up

As I have said many times, all oil is filtered before entering the engine by the best filtration system to date. Therefore, smaller debris carried in the return oil system will be filtered before re-entering the engine. However, I was uncomfortable with this "confined damage" statement when I first read it and increasingly so when customers asked me about it, which forced me to concentrate on it.



1999-to-Present Twin Cam Pinion Shaft

Pictured is a 1999 to 2006 right-side TC88A (Dyna and Touring) flywheel, also known as the pinion-side flywheel. Its 2007-to-present counterpart looks the same, but the crank pin location radius moves $^{3}/_{16}$” closer towards the flywheel rim. The 2007 engine stroke is 4 ⅜”, which is closer to the flywheel rim by ⅜” ($^{3}/_{16}$” radius) from 1999 to 2006. Shown to the right of the pinion shaft is the hollow crank pin end with its pressed-in end cap that allows a cooling oil reservoir to exist in the heart of the engine. The crank pin is pressed-in with a .007” interference fit into each flywheel half, thereby connecting and holding together the flywheel assembly. Cast, as one piece and integral are the pinion shaft and pinion flywheel. The TC88 pinion shaft is 40% thicker (.400”) than its Evo counterpart at the pinion-bearing location adjacent to the flywheel face. The rotating pinion shaft ultimately drives the oil pump, cams, and the valve train. Going up from the flywheel out, the thickest portion of the shaft is actually a pressed-on race further held in place by a circlip. The biggest pinion bearing (24623-99) located in the engine casing in the history of Harley supports this section of the shaft. The TC88B Softail pinion shaft has a sprocket mounted on it before this race to power the balancers and balancer chain. This balancing assembly takes up the space where an oil blowby protective S&S Reed Valve can be used on the A models and is the reason there is no room for it on the B models. The next reduced-diameter section is outside the bottom-end compartment and is the first portion protruding into the timing compartment on the A engines. The aftermarket Reed valve installs here. After the next step-down is the slotted portions on both sides of the shaft, where similarly slotted oil pump geroters sit on the shaft. The rotating shaft drives the oil pump (26035-99, 26035-99A, 26037-06). The oil pump body housing the geroters (26464-99 feed set; 26465-99 return set) mounts to the inboard side of the cam support plate (25267-99, 25267-99A, 25267-99B, 25355-06). The next smaller diameter section with the oil feed hole sits in the pinion shaft bushing (25344-99) located in the cam support plate. This bushing replaces with a parent material bearing in 2011. The oil pump feeds oil into a similar feedhole in the bushing and into the pinion shaft for delivery to the crank pin, bottom-end bearings, and con rod races. The worn section of this shaft indicates that it may be out of true. This will ream out the softer pinion bushing causing a loss of oil pressure, not to mention a source of vibration. The pinion shaft finally sticks through the cam support plate with a slotted end on one side only. The primary cam drive sprocket, similarly slotted, mounts onto this section and a bolt that threads into the end of the pinion shaft ensure the sprocket stays there. The pinion race, circlip, and flywheel pinion shaft sprocket (TC88B) do not have separate part numbers as they are furnished as part of a much larger kit. The TC88A flywheel assembly (23957-99, 23729-07) has the pinion race and clip installed on its pinion shaft. Also the Twin Cam 88B flywheel assembly (23912-00) has the center counterbalancer sprocket, pinion race and clip installed on its pinion shaft.

1999-to-Present Twin Cam Pinion Shaft

> Later manuals show the retaining ring (H-D 11177A) as a part that may be purchased separately. After all, the retaining ring must be removed to replace the TC88B sprocket. The center sprocket may also be purchased in the TC88B counterbalancer chain drive kit (14762-00) that includes all three sprockets, fore, aft, and center along with the attaching chain. Lastly the flywheel crankshaft (23957-99) comes as an assembly with pinion and sprocket shaft flywheels and integral shafts, crankpin, bottom end bearings and cages, flywheel thrust washers, connecting rods with parent material bearing big-ends and installed wrist pin bushings in the small ends. None of these parts are sold separately.

Owning a Harley-Davidson is a very personal thing. It fills and enhances voids in the psyche. The saying is true: It is more than a machine. The thought of carcinogenic metal debris circulating inside their engine compartment is disconcerting to say the least for all riders.

Harley engineers had also taught me that any engine damage would be contained and confined to the affected compartment and the return oil system.

The Evo has two compartments, which are the bottom end/timing chest and the top end.

- The Twin Cam has three, the top end, the bottom end, and the timing compartment.

As I have said, knowing the design of the TC88s, I can theoretically agree with this containment statement up to a point. Certainly large pieces of debris will likely be contained but what about finely ground up metal? Let's once again review background material that will demonstrate with clarity how accurate the H-D claim is. Wishful thinking can interfere with logical thought.

Gravity Oil Transfer into the Timing Chest

It is possible for larger contaminants to flow out of the bottom end compartment immersed in transferring oil. Downward piston evacuating air will facilitate this transfer.

The Pinion Shaft Bearing

Directly opposite the inside of the timing cover at the other side of the timing compartment is the huge pinion shaft bearing located under the inner INA inboard cam journal support bearings. This huge roller pinion bearing supports the right side of the crankshaft. It sits inside buttressed by the inner-right-hand engine casing. The pinion shaft extends through the middle of this pinion bearing, which supports the right side of the flywheel assembly.

Air is able to travel through the spaces between the individual pinion rollers and their mating individual cages. Much air travels back and forth through the pinion bearing rollers from the bottom end compartment and the timing chest compartment forced from side to side by descending pistons displacing air and ascending pistons creating a negative pressure (vacuum).

The same forces push air up into the top end compartment and pull it back down again. Air travels throughout the engine at the will of physical forces.

The Mystery of Traveling Debris Unwinds

Factory engineers had taught me that the three Twin Cam internal engine compartments are separate. They are…except for the transfer of gases! I did not think about this much in the beginning.

We do extensive Twin Cam engine work at Heavy Duty Cycles, so over time we get to see a lot. Back to Stevie, my head wrench for over two decades, who showed me the aforementioned set of pistons he had just removed from a Twin Cam. Fine shiny metal particulate impregnated the piston walls. There are two possible sources for the delivery of this particulate that embedded in the piston thrust surface skirts:

1. Oil squirted underneath the piston crowns by the piston jet (22307-99) at the right-side base of each cylinder. Piston jet oil has been recently filtered by the most efficient 10-micron oil filter to date. Therefore, it is highly unlikely that this amount of metal particulate would have made it through the filter.
2. The rotating flywheels pick oil up from the bottom of the engine casings. The oil flings via centrifugal force up onto the cylinder sleeves, lubricating the cylinder walls and pistons. This is the likely source but the question of originating metal debris in the bottom end compartment still needed to be addressed.

The engine had to come apart. In my opinion, it is the only way to thoroughly clean all the affected parts for metal contamination.

Diagnosing metallic Debris in an Engine

Hardened steel metal specks are bright silver and shiny, brass or copper are golden; shiny or dull, and aluminum is dull gray.

There are few places the shiny silver particulate could have come from, the most obvious being badly wearing bottom-end bearings; however, some of the impregnation was golden-shiny. There are no brass bushings in the bottom-end compartment except the piston pin bushings, but there is also one in the cam support plate in the timing compartment. However, if you push the con rod assembly to one side of the flywheels, you expose a gap down the side of anywhere between five and twenty-five-thousandths of an inch (.005" and .025"). You will notice a brass thrust washer on either side of the con rod big ends. The *big ends* refer to the connecting rod portion that houses the crank pin and crank pin bearings as opposed to the small ends at the top of the con rods that attach to the pistons via the wrist pin.

Take a concentrated flashlight and shine it down between the connecting rod big ends and the inside of the flywheels and you will better see the brass flywheel thrust washer on either side. On Evolution and Shovelhead engines, this brass thrust washer on either side of the big ends or their predecessor steel thrust washers, stake into an indentation of the inner side of each flywheel. The staking prevents the washers from moving. Their purpose is for a slippery and smooth surface to interdict the rotating connecting rods housing the crank bearings and their cages instead of them contacting the flywheel itself.

Twin Cam brass thrust washers are free-floating, supported on their 1 $^{11}/_{16}$"-centers hugging a very much fatter crank pin than previously used on all Harley-Davidson's. There is still a round 2 ¾"-diameter indentation in each inner flywheel half for the brass washers to ride in. However, the washers are not totally round on their outer circumference. There are two flat cut-off areas about 1 ¼" long diametrically opposed to each other.

Slowly rotating the flywheel assembly by hand in the engine casings after the top end has been removed will allow a patient and careful observer to see if there is any wear on these thrust washers.

It is also possible that the golden particulate came from the wrist pin bushings in the connecting rod small ends. These bushings support the piston wrist pin that attaches each piston to its connecting rod small end. A quick feel for excess tolerance confirms the source of particulate is not from here. Removing the wrist pins and their mating pistons allows a visual examination of the wrist pin bushings, which confirms that this is not the source.

Twin Cam Flywheel Assemblies

Harley does not sell individual flywheel assembly parts. Purchase of a complete flywheel set (TC88A 23957-99, TC88B 23912-00, TC96A 23729-07) is necessary. The part numbers quoted are for the first TC88 and TC96 Twin Cam flywheel assembly. As the Factory makes changes and improvements, the numbers will progressively change or have a letter like A, B, or C, etc. added to the end of the original part number. By year 2006, the TC88A flywheel part number became 23957-99D, indicating a series of four upgrades over seven years. Softail cranks have a different series of part numbers (TC88B 23912-00) primarily because of the inclusion of a center counterbalancer sprocket adjacent to the right flywheel face. This is one more item in an H-D engine that is not rebuildable now since the aftermarket has not remanufactured any of these parts at the time of writing.

Floating Flywheel Thrust Washers

In this particular bike, there was no thrust washer wear. It is important to check this since we recently had to rebuild a Twin Cam Dyna because one of these thrust washers interfered with the connecting rod rotation. The pounded thrust washer eventually was ground into a fine powder.

Since the thrust washers are free floating, what caused this? In these situations, I always look for gas mixed in the oil, which turns the lubricant into an abrasive. This is common on older motorcycles where the owner leaves the petcock on all the time or the petcock wears and starts to leak gasoline into the cylinders, washing them down and leaving no lubricant. This was not the case since there was:

A new automatic vacuum-operated petcock on the bike that tested fine.

1. No smell of gas in the oil.
2. The lack of visual wear characteristics or worn parts refuted this possible cause.

My conclusion in this case was that the flywheels pressed together too tightly in assembly at the Factory, not leaving enough tolerance between the thrust washers and the flywheels. Fitment specifications are all about leaving enough room and then some to take up metal expansion characteristics.

Worn Pinion Shaft Bushing in the Cam Support Plate

The removal of the timing chest parts before the top end was fortunate in a very unfortunate situation for the customer. The wearing parts I discovered told me the source of the metal embedded in the piston skirts but it is necessary to be thorough, which is why the wrist pin bushings and flywheel thrust washers also be examined. I found that:

1. The cams four-lobes were wearing badly.
2. And so was the support plate bushing that was, in my opinion, the source of the golden shiny grains embedded in the piston skirts.
3. The timing chain adjusters also needed replacement.
4. Further examination revealed that one of the cam support bearings was beginning to spin in the cam-support-plate.
5. Furthermore, so were INA rear-journal-cam bearings that fit into the engine casing.

This engine was going to blow sooner rather than later.

Some days in dealing with customers, I feel like a doctor in a terminal cancer ward where there is little or no good news. The engine needed rebuilding. However, in order to do the job right, the bottom end still had to come apart for inspection and, at the very least thoroughly cleaned to free it of destructive particulate.

We are seeing timing compartment adverse wear, and thus damage, on a regular basis on 1999 to 2006 Twin Cams! Of course, no one brings me a motorcycle in perfect running order to disassemble. However, I do find hidden or unknown damage when taking apart perfectly good engines for hi-performance work.

Oilified Gaseous Air Transfer

Gases transfer between the inside of the crankcase and the timing chest through the pinion-bearing rollers. Air displacement as the pistons move up and down their respective cylinders causes this. The descending pistons decrease the air volume capacity of the bottom-end crankshaft compartment. Decreasing space pushes the gaseous air out of the bottom-end compartment through the pinion bearing back into the timing chest and up the pushrod tunnels into the top-end compartment. Then the ascending pistons in turn create a vacuum in the bottom end. This vacuum draws the internal oilified mist back through the pinion bearing rollers from the timing compartment.

Furthermore, the mist residing in the two top-end wafer compartments atop both cylinders draws down the pushrod tunnels and the top end oil return holes first into the timing chest and then back into the bottom-end compartment. This rpm cycle happens from a few thousand to many thousands of times a minute. Rpm is the acronym for engine revolutions per minute.

Two 360-degree revolutions for a total of 720-degrees constitute one complete cycle of four strokes: intake, compression, power, and exhaust.

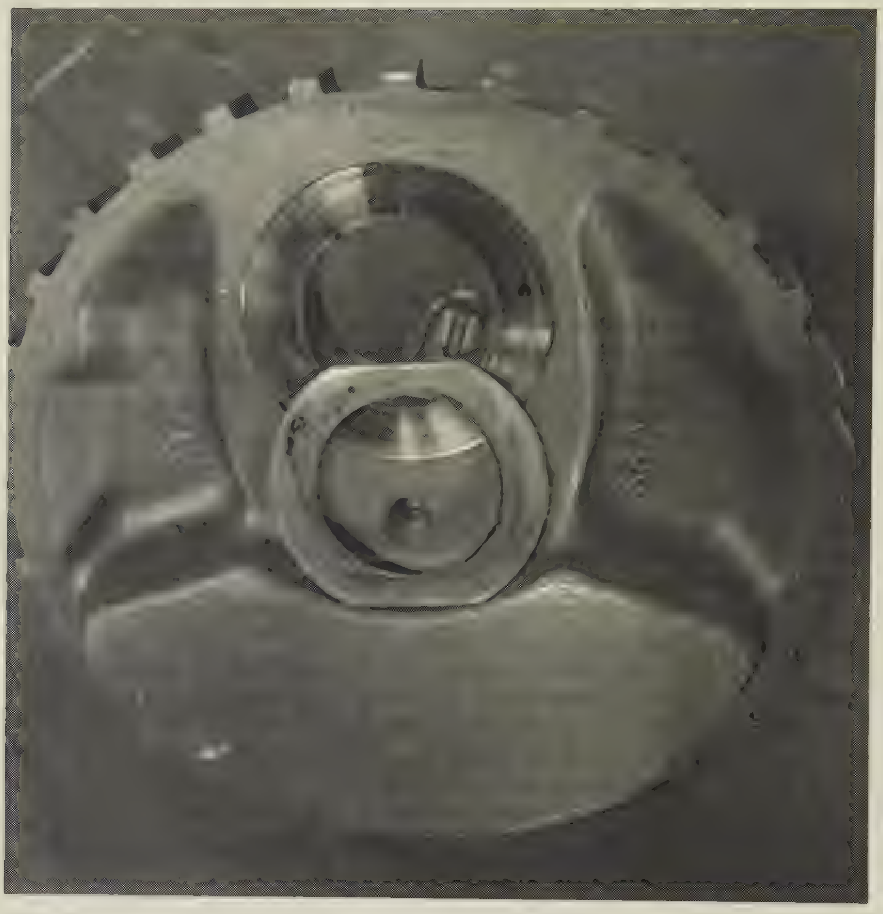
In Big Inch Twin Cams, modest 95-inchers, and/or in bikes ridden at sustained high rpm speeds, this transfer of air increases in both volume and rapidity of transfer.

Consider what would happen if the gaseous mist were carrying hardened metal fragments from wearing cams and bearings to other hardened parts in separate compartments. Parts such as bottom-end bearings, valve stems, or especially relatively softer components such as aluminum pistons and the cast iron cylinder sleeves, will become vulnerable.

Oilified Gases Start Out as Air

The mist starts out as air, which fills all the engine cavities. It is a dirty world inside an engine. The churning flywheels that push and pull the pistons up and down the cylinders cause the engine shafts to rotate, which drive the rotating cams, via fast-moving timing chains. The cams drive the four pushrods up while compressing valve springs to force valves to open and then force the valves to close, driving the pushrods down again.

1. Oil is a complex chemical once refined and infused with additives. One of its functions is to lubricate all of these moving parts as they interact with each other. Film strength of the oil allows the molecules to separate the moving parts from each other. Some of these parts, such as bottom-end bearings, are under tremendous pressure. This pressure helps break the oil down over time and usage, causing by-products.
2. Combustion also creates pollutants that enter the engine compartments via internal blowby. This type of blowby is the burning or burned combustible from the combustion chamber, expanding and forced by the rings that are supposed to seal them out.
3. Wearing parts also create small metal debris that carries in oil to the oil filter for removal. One of oil's many facets is to act as a transfer agent, carrying suspended unwanted particles and by-products in the liquid oil to the oil-cleaning filter.



Twin Cam Internal Flywheel Thrust Washer

Pictured is the inside face of the left-sprocket shaft Twin Cam flywheel. The cut notches are *read* by a crankshaft magnet sensor (32497-99, 32707-01) located in the front of the left-side engine casing to send information to the electronic control module (ECM, ECU or ICM, take your pick). The module will then know the piston locations along with other sensor data to time when the spark plug will ignite the fuel mixture according to the spark matrix map cell that corresponds most closely with incoming data. Both front and rear pistons are always in the same location in their respective cylinder bores. However, they are on opposite strokes. For example, if one piston is on its compression stroke, the other piston will be on its exhaust stroke. If the connecting rods in a set of assembled flywheels are pushed to one side, creating a gap on that side of anywhere between five and twenty-five-thousandths of an inch (.005" and .025"), portions of a brass thrust washer will be visible between the flywheel half and the con rod big end. In Evolution, Shovelhead, and Panhead engines, these brass or steel, depending on year, thrust washers are perfectly round and locate on either side of the big ends. They are staked into an indentation of the inner side of each flywheel and do not move. Their purpose is for a slippery and smooth surface to interdict the rotating connecting rods housing the crank bearings and their cages instead of contacting the roughcast flywheel itself. Twin Cam brass thrust washers are free-floating, supported on their 1 $^{11}/_{16}$" centers hugging a very much fatter crank pin than used on previous models. There is still a round 2 ¾"-diameter indentation in each inner flywheel half for the brass washers to ride in. However, the washers are not totally round on their outer circumference. There are two flats about 1 ¼" long diametrically opposed to each other. They float so as not to impart an inertial slowing and wearing force onto the rotating con rod big ends. The flats allow oil to get behind the washers into the round recess. All moving parts need a film of lubricant between them. There is no part number for these Twin Cam thrust washers or any separate numbers for any parts comprising the bottom-end crank. Harley does not sell them. A complete flywheel set (TC88A 23957-99 or subsequent number depending on year and model), must be purchased. This is one more non-rebuildable item in an H-D engine now since the aftermarket has not remanufactured any of these parts at the time of writing in 2010.

Oilified Gases Carries Minuscule Debris

All of the agitation caused by moving parts, parts interaction, and air displacement causes some of the oil to become gaseous and mix with the transferred air around the engine. Minute particulate and breaking down oil by-products suspends in this oilified mixture.

I agree with Harley-Davidson that the three engine compartments, bottom end, timing, and top end are indeed physically separate. However, the oil feed and return flow does cross all three compartments but the 10-micron oil filter cleanses it first.

Nevertheless, the suspended pollutants in the oilified gaseous mixture powerfully moved back and forth between the three compartments by the forces generated by the ascending and descending pistons thousands of times per minute are not cleansed right away. This is, of course, is how impregnation of the pistons with fine metal particulate occurred. This particulate originated in the supposedly confined timing chest!

Clean the *Whole* Engine after Severe Parts Wear

For myself, I would be very uncomfortable if I didn't disassemble the engine for a thorough cleaning if the timing chest components self-destructed.

The Twin Cam engines are the best ever produced by the Factory, but like all new product offerings there are teething problems. Problems not evident in the perhaps one hundred prototype engines appear in production engines where manufacturing tolerances are greater.

Bean counters trying to save production expense will sometimes unknowingly create problems.

- The riding consumer and his idiosyncrasies will explore areas of part stress not envisaged by the engineers.

You will know what I am talking about if you are an experienced motorcyclist. Pay attention to a new rider and the resultant torture imposed on the machine. Blown shifts sending rpm screaming upwards, lugging with too-low rpm in a too-high gear, and downshifting the engine before it is in a more comfortable rpm range are a few examples.

Why Didn't the Factory Figure out Problems Beforehand?

One might think that the Factory must have experienced some of the initial problems encountered with production Twin Cams during H-D's rigorous testing of the prototype motorcycles.

1. Sometimes it is less expensive to make changes on the run during the first production years.
2. Perhaps figuring out a solution to every problem before scheduled production must begin sometimes isn't possible.
3. Full design changes may take a long time. Stalling of new-model assembly is not an option.
4. The problems may not occur in every bike. A low-miler H-D owner that babies the motorcycle will certainly experience fewer bad situations than an aggressively riding high-miler will.
5. Warranty will deal with some situations.

There are many reasons that the Twin Cam engine's teething problems have reached into the production models. Despite all of this, the Twin Cam engine is the best ever built by Harley-Davidson!

Researching Service Recalls for all Years

The United States National Highway Traffic Safety Administration (NHTSA) has an office called the Office of Defects Investigation (ODI). Among other things, this department takes care of recalls.

The reader can learn whether there are recalls on his or her own Harley-Davidson by visiting *www-odi.nhsta.dot.gov/cars/problems/recalls/recallsearch.cfm*. The odd times I searched the web site I ran into technical difficulties with my browser. The reader can also go to *www.nhsta.gov* and click on Recalls.

As an example, I searched 2007 Harley-Davidson FXD at the time of writing this section in April 2007 and found that 614 certain Dynas and Sportsters were built with an incorrect front tire. The site gives the Harley recall number as No. 0129 with a corresponding NHTSA campaign ID number: 07V025000.

Harley-Davidson has also announced two voluntary service recalls that affect more than 28,000 bikes from model year 2007.

1. The first is Harley-Davidson No. 0127 with a corresponding NHTSA campaign ID number 06V474000 and is very serious. On 10,397, FXDWG 2007 Dyna Wide Glides, the hole in the handlebars where the handlebar wiring exits may crack. One of my fears has always been that the handlebars might break or separate from the front end. To quote the NHTSA site, "Dealers will replace the handlebar with one with a greater wall thickness and with a wire exit hole that has a shape that reduces stress concentration." [10]
2. The second voluntary recall, No. 0128, concerns eight models of the 2007 Sportster line. On these bikes, the rear skirt of the front fender can catch onto the top of the voltage regulator body hindering steering. The dealer will relocate the voltage regulator.

Recalls may not affect every model produced so it is important to check if your particular bike is on the recall list at Harley-Davidson 1-414-342-4680. You may also contact The National Highway Traffic Safety Administrations vehicle safety hotline at 1-888-327-4236 (TTY 1-800-424-9153) or go to www.safercar.gov. If the reader researches the site, it will become quickly apparent that there have been many recalls over the years that the riding public may never hear about. Of course, affected owners are sent letters, etc., but people move or may not always get their mail.

The site is very cool. It goes back to 1949 although the only vehicle listed is Volkswagen. I guess it was being closely scrutinized by the US government since it was only four years after WWII. Following a cursory search, the first entry for Harley-Davidson I found was for the King of the Highway, the 1967 FLH Electra Glide, which had a safety recall for 3,972 motorcycles for the rear hydraulic brake line that was missing an extremely important hold down clip. The hydraulic line could make contact with the rear wheel or siren rotor (police/military models) and fray. The line might also get caught between the rear crash guard and rear fork and sever.

I had a look at 1970 for the King of the Highway, the FLH Electraglide, and found that 12,963 units possibly had improperly tightened wheel-bearing locknuts. I thought that number would be around 35% of total production, which is very significant. *The Harley-Davison Data Book* says that not that many FLH's were produced in 1970, so the recall may have affected other models also. In fact, the book says that there were about 17,000 Harley's, including the GE 45 cubic-inch Flatheads and Sportsters. [11]

In any case, one can get lost in this stuff or at least I can.

[1] The National Highway Traffic Safety Administration National (NHTSA), Office of Defects Investigation (ODI); campaign ID numbers 99V291000 and 99V292000. Harley-Davidson. Year 1999, Model: FLT. Service recall M370, Oct. 22, 1999.

[2] Metz, Skip. Harley-Davidson Powertrain Program Manager. Numerous discussions with Skip Metz. Buzz Kanter, Chris Maida and Petersen and others present while on official visits by invitation of Harley-Davidson. Milwaukee March 1998 and York Plant, York Pennsylvania 1999.

[3] Ibid.

[4] Ibid.

[5] Ibid.

[6] Harley-Davidson. *2005 Harley-Davidson Service Manual – Touring Models 99483-05*: page 3-95.

[7] Harley-Davidson. Service Bulletin M-1097, *Cam Bearing Repair Kits.*

[8] Harley-Davidson. *2005 Harley-Davidson Service Manual – Touring Models 99483-05*: Page 3-95.

[9] Metz, Skip. Harley-Davidson Powertrain Program Manager. Numerous discussions with Skip Metz. Buzz Kanter, Chris Maida and Petersen and others present while on official visits by invitation of Harley-Davidson in Milwaukee March 1998.

[10] The National Highway Traffic Safety Administration (NHTSA), Office of Defects Investigation (ODI); http://www-odi.nhtsa.gov/cars/problems/recalls/results.cfm campaign ID numbers 06V474000. Harley-Davidson. Year 2007, Model: FXDWG. Service recall 0127, Dec. 12, 2006.

[11] Connor, Rick. *Harley-Davidson Data Book*. Osceola, Wisconsin: Motor Books International, 1996. Page 115.

CHAPTER III

Timing Chest Breakdowns and Solutions

I will discuss two major solutions for 1999 to 2006 timing chest breakdowns in this chapter:

One a dramatic design change instituted by Harley-Davidson.

1. A subsequent reactionary one from the aftermarket.

The Factory quest to lessen noise generated by internal mechanical gears was accomplished by replacing the gear interaction with timing chain-driven sprockets. I will discuss this at length, examining where the noise comes from and why the solution is not sometimes quieter. The aftermarket solution was not to react to the H-D attempt to lessen noise but to:

1. Repair the problems that the timing chains and their component parts were causing.
2. Find a solution for the effective use of stronger seat valve springs that allow higher lift performance cams.
3. Create a market for its own benefit.

I am sure, the aftermarket could have come up with a solution utilizing timing chains but they eliminated them in favor of going back to a precise gear drive system!

Are Timing Chains quieter than Gears?

As I go through the circle of design changes, we will see that not all is, as it seems. For example, it is taken as a given that the timing chains are quieter than the timing gears. This given becomes a truth if comparing an Evolution timing chest with interacting gears to the hundred or so prototype Twin Cams used for testing before actual mass production began. The *prototype* timing chain system was indeed quieter than the gears.

It is also taken as a given that aftermarket Twin Cam gear drives should be noisier than the timing chain apparatus. If comparing noise levels of production Twin Cam timing chain engines with the aftermarket cam gear drives a new truth emerges because some 1999 to 2006 timing chain compartments:

Produce less noise than the cam gear drive.

1. Some produce approximately the same noise.
2. And some produce more noise.
3. I feel the reason for this is that the necessary wider variance in acceptable mass-production tolerances and specifications makes some Twin Cams as quiet as the prototypes, some noisier and some noisier still.

The 2006 TC88 Dyna and all 2007 and later TC96, TC103, and CVO 110 Twin Cam engines are consistently less noisy than gear drives as well as the 1999 to 2006 silent cam chain drives. This is due to the constant hydraulically-tensioned timing chains, which dutifully follow the primary and secondary adjuster dictates. No more can they petulantly overwhelm their hydraulic adjusters as with the precedent 1999 to 2006 spring-loaded adjusters. It is true that the new roller chains should be slightly noisier than the early silent drive chains but it is also true that noise generated is consistent and not all over the spectrum from bike-to-bike.

Where Does the Noise Come From?

Let's start at the beginning where the ever-increasing emissions dictates of the U.S. government forced Harley-Davidson to alter its engine configuration.

The three main factors that contribute to noise on a modern motorcycle are:

1. Exhaust mufflers.
2. Manifold air intake.
3. Gear interaction.

Everyone understands that the exhaust mufflers dampen noise considerably. Hardly anyone thinks of the air rushing through the manifold intake as being a contributor of noise.

The interaction of spur timing gears inside the timing chest located just below the carburetor, or the fuel injection as the case may be, was a big source of noise until the advent of the Twin Cam. In addition to timing chest spur gears, all H-D five-speed Big Twin transmissions have five sets of spur gears interacting for ten gears in total.

Transmission Gear Noise

The four-speed models have four sets of spur gears for eight gears, in total. One might think them quieter than the five-speed since there are two less spur gears to make noise. In fact, the four-speed is much noisier because little thought was given to manufacturing the mating gears to a closer tolerance until later 4-speed years.

They did begin the use of full-contact ratio gears where the gear faces are reshaped to roll into each other.

1. The technology did not exist prior to 1986, when the 1986 FXWG-Wide Glide model utilized the last four-speed transmission to grind high spots off the gear faces after the hardening process. The process referred to as *full contact gear interaction* and described previously in Chapter I: *March 1998: Introduction of the Twin Cam* lessened mechanical gear noise considerably but over time proved to be just another stopgap measure.
2. I almost wrote that the 1985 Softail was the last year of use. It is amazing how one can temporarily forget what one knows like the back of his hand. I was rereading the book before sending to the publisher and saw my mistake and a dumb one it almost was.

Spur gears are not always in full contact with their mating gear allowing the potential for noise such as backlash as they mesh under load.

Helical Gears a Failure?

In an effort to reduce gear noise, the 2006 Dyna and all 2007 to 2009 Big Twin six-speed transmissions use spur gears in 1st and 5th gears and utilize quieter helical gears for 2nd, 3rd, 4th, and 6th gears. In 2010, H-D figures out how to overcome helical gear side thrust issues and replace the troublesome 5th spur gears with helical ones. All Cruise Drive 6-speed transmissions use a 1st spur gear combination.

Helical cut gears are not straight across but slanted. They are always in contact with their mating gears. I will demonstrate in coming chapters that the transition to helical gears in the new 2006 Dyna and all 2007-2008 6-speed transmissions is thus far pretty much a failure in the noise-dampening department. Changes to the new Drivetrain and the 6-speed transmission will evolve because of this.

In 2008, the former solid rear-wheel-drive belt pulley replaces on touring models with an isolator 6-rubber absorption pulley sprocket that effectively stops reverberating power pulses travelling back-and-forth along the powertrain (Drivetrain) components.

1. In 2009, H-D began to use a 7% stronger compensator to control engine power pulses that inexplicably were the power source of the 6-speed transmission noise.
2. In 2010, H-D replaces the problematic 5th spur gears with a helical set plus a minor main shaft and guide hub redesign to make this possible.
3. In 2011, all touring models begin use of the Screamin' Eagle compensator sprocket design already having fitment on CVO S.E. models, Trikes, and the FXCWC.
4. I will cover these developments at length in Chapter X: *The Controversial Harley 6-speed Transmission* as well as in Chapter XV: *2010 Model Changes*, section, *Cruise Drive 6-speed Transmission Upgrades.*

Transmission Gear Noise is Muffled

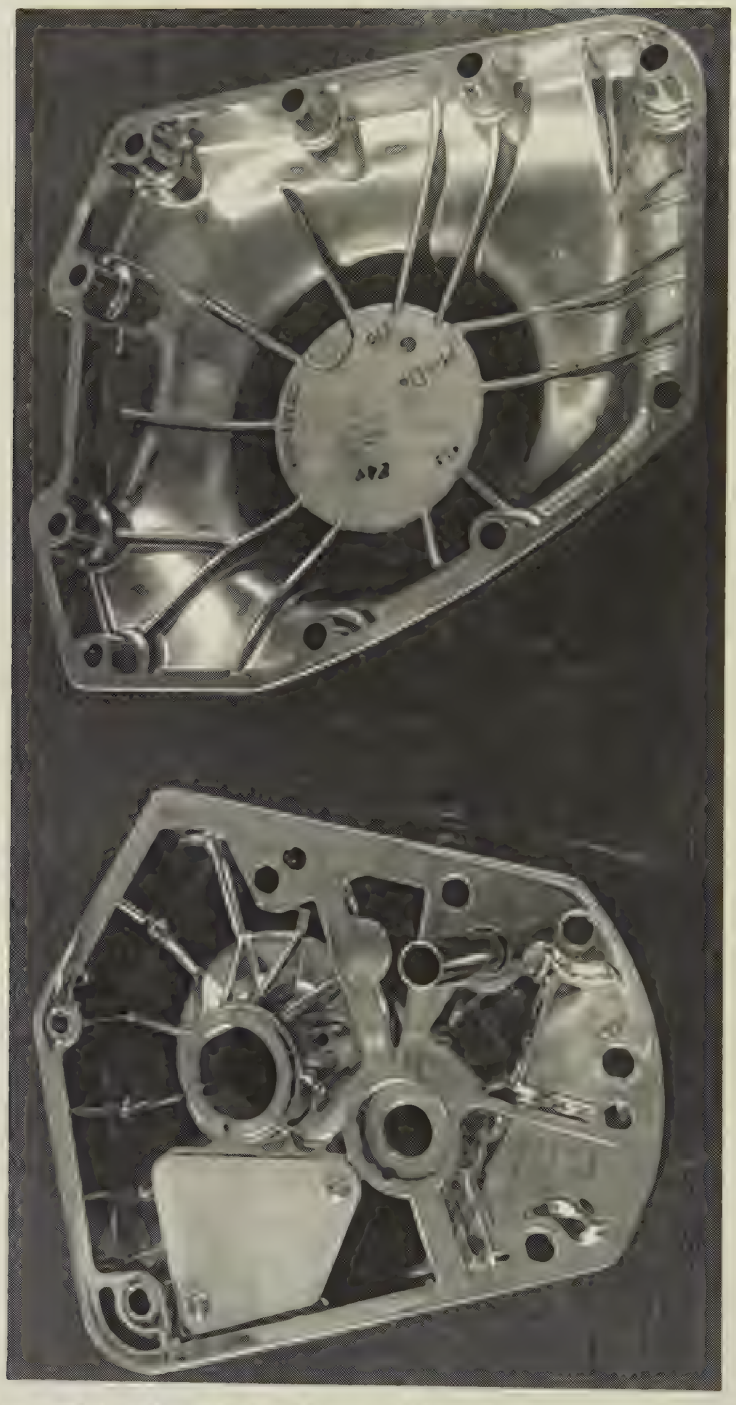
Encased in thick aluminum housing, transmission gears are not the first area of attack in noise reduction.

The casing dampens noise travel better than the exposed timing chest.

1. The clutch actuating mechanism and cover on the transmission right side also dampens gear noise.
2. The primary chaincase on the left side of the transmission with noise-dampening internal ribbing and its component parts like the clutch and primary fluid absorbs generated transmission gear noise.
3. The transmission underside faces the ground.
4. Rubbermount FLT/Dyna models with their oil tanks located underneath absorb and muffle downward noise very effectively.
5. Above the transmission as well as the front and rear, portions face other motorcycle components, which deflect and absorb some of the gear noise.
6. Finally, Harley transmissions unlike their compatriot V-twin engines have a wet sump oiling system, which means there is no separate-feed oil reservoir.
7. The reservoir is the transmission casing. The gears are more than half immersed in almost a quart of thick noise absorbent 80/90-weight hypoid gear oil. The remaining portion of the gears above the oil line always have a thick coating of oil being flung over them as does the exposed internal transmission casing. Hence, the reason some transmissions make more annoying noise when lubricated by the 20W50 Harley-Davidson SYN3 oil. The cure if required at all is sometimes to go back to the 80/90-hypoid-gear oil.

H-D engines have dry-sump oiling systems where the oil reservoir is separate from the engine components. Oil feeds into the engine for lubrication, pumps out continuously removing heat, and dispersed particulate. The engine internal space is very much larger than the relatively small transmission casing, and yet there should not be more than six ounces of oil in the bottom end at any given time. Too much oil inside the engine causes an inertial drag on the rotating flywheels and a corresponding parasitic loss of internal horsepower.

Engine spur gears located in the timing chest transfer noise to the outside world because of a lack of effective dampening mechanisms not the least of which, is positioning.



Evo + Twin Cam Engine Timing Chest Compartment Covers

Pictured on the top is a 1999-present Twin Cam timing cover (25369-01 chrome) over a Shovel-Evolution 1973-1991(25268-84A chrome) timing cover on bottom. Harley used three different part numbers to cover these years 1973 to 1991, but they are interchangeable for the knowledgeable mechanic. The Shovel-Evolution cover is load bearing. The upper (left) bushing supports the outboard cam journal. Evolution cams are in-line with four cam lobes that actuate the four individual valve trains usually referred to as the valve train. The cover must support much weight and rotational stresses. The lower (right) bushing is the pinion shaft bushing. The pinion gear located just in front of the cover bushing on the rotating pinion shaft drives the cam and the valve train. An oil-drive gear behind the pinion gear drives the oil pump-drive gear, which powers the four oil pump gears (two feed and two returns). Unless the pinion shaft is true to its pinion (right) side flywheel to less than .002" (I prefer .000" to .001"), runout it will create mild to wild havoc depending on the amount of runout with the timing cover bushing to the point of reaming it out. Oil feeds through the pinion bushing into a mating hole in the end of the pinion shaft to feed the bottom-end bearings, crank pin, and connecting rod races. Oil pressure will suffer unless the pinion shaft end to bushing fit is within specifications, which will be impossible if the shaft is out of true. With this all too common scenario, the shaft will also dislodge the timing cover slightly, moving it back and forth, ruining the gasketing seal. The flat steel plate is a baffle. Oil vapor runs up against it on the inside, separating the air. Oil runs down the plate via gravity whereas the air continues down an internal passage between the two bushings and exits out the tube to the engine vent. The Twin Cam cover is a cover only. Its only functions are to seal the oil inside the engine and to dampen engine noise. The cam support plate in the timing compartment that bolts firmly to the inside of the right-hand engine casing supports the cams and timing chain sprockets. On the Twin Cam, the timing, tappet, and rocker covers are just that. Evolution and predecessor engines have these same covers in different configurations, but they are without exception load carrying and prone to oil weepage or leaking. There is further testament to Twin Cam superiority. Notice that there are six hold-down screw holes (the seventh and eighth are dowel pinholes and the ninth is an oil passage feed), in the stressed load bearing Evolution cover. There are 10-hold-down screws for the non-stressed Twin Cam cover. Twin Cam gasketing and materials are also very much superior to what went before.

Noise and Harley-Davidson go Together

The maximum noise decibel (dB-a) number of 80dcb in 1999 will reduce as the years roll by.

H-D is in a difficult situation, since noise is part of the expected riding experience. It is difficult to imagine a silent Hog, but that is where it is all going. I am sure that the Factory will be marketing a quieter experience as being desirable as time goes on. Re-educating new riders is the necessary strategy. Already, in 2006 Harley is voicing responsible riding discussions around the topic of noisy mufflers.

Noise and Harley-Davidson will take Separate Paths

Some of us will not like this. The future holds much more on the horizon for traditionalist riders that do not like change. Electronic fuel injection will mostly replace carburetors in the next five to seven years (written in 1999). There will be no H-D equipped carburetors at all within the next ten years. Stepping into the future, 2007 became the year that every Harley-Davidson including Sportsters began to utilize EFI.

Overhead cams, directly actuating the valves will sometime after 2010 replace the dinosaur valve train that we love, eliminating remote location cams, lifters, pushrods, and rocker arms. If this does not happen, which my crystal ball says it will, at the very least quieter serpentine or carbon fiber belts will replace the current Twin Cam timing chains. Stepping once again into the future, 2010 has not brought overhead valves to a Twin Cam successor yet but The V-Rod and the Buell 1125R both have water jackets and overhead valves. Each is marked as the successor for current old-school-technology models. The Great Recession will slow this progression down dramatically and in fact causes the discontinuation of Buell in late 2009.

Bob Wood of Wood Knight Prowler cams fame (www.woodcarbs.com) has already replaced the timing chains with a kit that he has developed using a carbon fiber belt to power the pinion and rear-cam-gear drive-pulleys replacing the outboard sprockets and primary drive chain. This 5mm reinforced carbon fiber belt connects the replacement drive pulleys powered by the rotating pinion shaft. I use the H-D nomenclature for the sprocket/pulley for reference only as Bob's invention utilizes a 5mm cam gear with an adjustable spider gear.

Bob probably will not like me calling him an inventor since he is pleasantly unassuming. He feels he has just adapted automotive technology. Maybe so, but I think he is a pretty inventive person with a knowledge base that surpasses most in the Harley world.

His pièce de résistance for this timing chest fix is the use of quieter full-contact helical gears to drive the gear drive cams instead of noisier spur gears. I will be looking at Bob's innovative drive system in detail in Volume II: *Performancing the Twin Cam,* Chapter II: *Repairing the Achilles Heel,* section, *Knight Prowler (Silent) Advanced Belt Drive System.*

You know, I can see Bob's ideas incorporated into future Harley design, especially if the revamped timing chain system introduced with the 2006 Dyna becomes problematic over time.

Let's not even think about a water jacket enclosing our beloved engine with a big cooling radiator out front! All of this will be necessary at some point in the future for controlling noise. The water jacket will effectively jacket any internal din but will also allow the engine to operate at a consistent and lower temperature. This will have a huge impact on mechanical efficiency, thereby allowing a systematic attack at reducing exhaust emissions not available to air-cooled Harley's. I am already hearing unsubstantiated rumors from people that I trust that H-D is developing its first water-cooled Baggers. We will see, but it is a certainty at some point. These predictors also say that, like the V-Rod, it will incorporate a 60° engine. Perhaps it will be a V-Rod engine…well, of course it will be!

Year 2010 will see new emissions dictates, which lends credibility to the rumors.

Of course, catalytic converters in the exhaust may become another stopgap measure.

- The new Bagger exhaust in 2009 contains a collector housing. California bikes in 2009 outfit with a catalytic converter that is contained in this housing.
- Well, all 2010 Harley-Davidson production also contains an exhaust catalyst in this housing.
- It's all coming out of necessity, sooner rather than later.

The ride by decibel testing is a measurement of all three sources of noise: exhaust, manifold, and mechanical. Since a throaty exhaust sound is highly desired by the Harley crowd, the Factory works hard at reducing intake manifold and mechanical gear noise. Lowering these two noises will allow the throaty sound of the exhaust to remain and even become more apparent. However, even this is also a stopgap measure. A water jacket would go a long way in suppressing noise to meet regulations further allowing a louder exhaust. You know, the reality is that this too would only be temporary. In the end, Harley-Davidson will no longer be defined by its unique sound because there will not be much sound, if any at all!

Pushrod Engines 101

The cam compartment timing gears are necessary in the Evolution and predecessor engines to transfer rotating power from the crank to the cam lobes, which actuate and operate the valve train. The crank consists of the flywheels, supporting flywheel shafts, and the connecting rods. The pistons attach via wrist pins to the upper ends of the connecting rods known in mechanic-speak as the small ends. The supporting flywheel shafts transfer power out both the right-pinion side to drive the cams plus the rest of the valve train and the oil pump. The left-side sprocket shaft transfers power back to the rear wheel via the powertrain.

The outside flywheel shafts locate in the center of the flywheels with the inside crank pin offset from center. This offset moves the con rod appendages up and down as the wheels rotate.

The 4-stroke Engine

The rotating flywheels push the pistons up and pull them down the cylinders four times to complete a cycle.

Each of these four strokes requires 180-degrees of crankshaft rotation.

1. The pistons move up and down their respective strokes in tandem with each other. Each piston travels up its respective cylinder at the same time and each move down together.
2. However, each cylinder is on a different stroke than its mating cylinder:
3. If the front cylinder piston is beginning its cycle on its downward intake stroke the rear cylinder piston will be on its downward power stroke.
4. As the front piston moves up its compression stroke, the rear piston is on its exhaust stroke.
5. The front piston then descends on its power stroke while the rear piston travels downwards on its intake stroke beginning its cycle.
6. Finally, as the front piston ascends on its exhaust stroke finishing its cycle, the rear piston is on its upwards compression stroke.

This cycle of four 180^0 strokes requires 720^0 of crankshaft rotation to complete before starting all over again. Furthermore:

1. The rotating flywheels pull the piston down the cylinder bore via the connecting rods on the intake stroke to draw in air and gas.
2. The piston actuated by the now ascending con rods push up each bore on the compression stroke, squeezing the air and gas mixture into a smaller space, the combustion chamber.
3. The spark ignites the mixture, creating heat that expands driving the piston down the bore on the power stroke. This stroke forcefully rotates the flywheels to transfer torque power back to the rear wheel via the sprocket shaft and through the powertrain to drive the bike go forward.
4. The last stroke is the exhaust whereby the rising piston will force the burned gases out the exhaust pipe, thereby completing one 720^0-rotation cycle of this four-stroke engine.
5. Thus, the engine must rotate two complete 360^0 circles, so to speak, to complete a full cycle of the four strokes with each stroke representing 180^0 of crank rotation.

Pinion Shaft Function

The right-hand flywheel pinion shaft protrudes through the bottom end compartment into the timing compartment supported by the pinion bearing located in the separating engine casing wall.

Mating gears on Evolution and predecessor engines or sprockets with timing chains on the Twin Cam engine attach to the rotating pinion shaft in order to power the camshaft(s).

- Evolution and predecessor engines have a gear on the pinion shaft that drives the gear-driven oil pump.
- Internal oil pump feed and return geroters actually sit on and are driven by the rotating pinion shaft in Twin Cam engines.
- The single or dual cams, depending on the engine, four elliptical rotating lobes operate the four valve trains, one for each of the four valves.
- There are two intake and two exhaust valves in all Harley-Davidson overhead (OHV) valve engines from 1936 to present.
- There is one intake valve and one exhaust valve per head on traditional H-D 1936 to present Big Twin and 1957 to present Sportster engines.

Engine Parts Time to Each Other

1. Flywheel components all attach to each other thus, the mechanic and the electronic control module or properly adjusted ignition points system times exactly to where the pistons are in their respective cylinders and how fast they are moving.
2. An attached pinion shaft gear or sprocket times to the pinion shaft via a keyway, spline(s), or an internal slot as with the Twin Cam.
3. This pinion shaft gear or sprocket times to the camshaft drive gear or sprocket. In the case of a dual cam engine like the Twin Cam the rear cam times to the pinion shaft gear, which drives and times to the front cylinder camshaft. In this way each camshaft lobe, one for each valve train and valve, times the opening and closing of the valves to piston location, direction, and speed.

4. This is all necessary for coordinated functioning of engine components in relation to each other so the mechanical point's ignition system (1936 to 1978), hybrid systems (1978 to 1982), solid state electronic ignitions (1983 to 1994), and electronic engine management systems that began in 1995 and continue to present day with ever-growing sophistication can time and ignite the spark plugs. The spark plug ignition timing ensures that maximum combustion can occur to drive the pistons down on their respective power strokes for optimal power.
5. The only moving internal parts that do not need to time to the rest of the components is the oil pump because it must function steadily and consistently all the time.
6. The external 1936 to 2000 oil pumps are driven by a pinion shaft gear on the pinion shaft that meshes with an oil pump drive gear inside the timing compartment that connects to and drives the feed and return oil pump gear sets via a shaft through the crankcase.
    a) The Twin Cam oil pump feed and return geroter sets are driven by the pinion shaft itself. The oil pump sits on the shaft. The inside feed and return geroters have an inner diameter slot that fits over and mates with an identical slot on the pinion shaft. These geroters are driven by the shaft directly with the oil pump body firmly attached to the inboard side of the cam support plate.

Nosecone Timing Gears 1970 to 2000

On pre-Twin Cam Harley's, the nose-cone-shaped timing-chest gears consist of the breather gear, the cam gear, the driving pinion gear, and the oil pump-drive gear. Some may question my delineation of the year 2000. Twin Cam touring and Dyna models began in 1999. The Evolution Softail models continued into 1999 becoming Twin Cams in 2000. However, the first Screamin' Eagle CVO models were Evolution FXR based. The FXR^2 and FXR^3 were 1999 Evolutions while the FXR^4 was the last Evolution model in 2000.

Kidney Timing Gears 1927 to 1969

The pinion drive gear on the pinion shaft powers the cam gear, which in turn powers the breather gear. However, there were additional gears in the kidney-shaped timing chest on 1969 and earlier Harley's.

The circuit-breaker-drive gear times to the cam gear because its attached rear portion also drives the distributor in use on these earlier models. The points and condenser ignition sit inside the distributor's cap below the front-right-side of the front engine head

1. Attaching behind the spur circuit breaker gear was integral, crude by modern standards, helical-cut gear that interacts and drives a mating distributor circuit breaker helical drive gear. The pre-1970 circuit breaker crude helical gears while slanted still created backlash noise because their interaction was not continuous like a full-contact modern helical gear exampled by those used in the Cruise Drive six-speed H-D transmissions. The reason for the circuit breaker gears timing to the cam gear is obvious when thought through. The cam gear drives the four cam lobes that move the valve train and ultimately open and close the valves in tandem with the piston location through the four strokes of the engine cycle. The distributor circuit breaker opens and closes the mechanical points-condenser ignition system, which fires the spark plug to ignite the gas.
2. The front spur gear portion of the circuit-breaker-drive-gear further drives the idler gear at the front of the timing chest. The cam gear is positioned on the left (rear) while the idler gear sits to the right (front) of the circuit-breaker-drive gear

3. The spur idler gear, in turn drives the spur generator gear. The idler gear and generator drive gear do not time to other parts because like the oil pump, it functions constantly, one supplying oil pressure and the other DC electricity.

The generator charging system is in use on all pre-1970 Big Twins. The generator bolts to the front of the right side engine case on an appendage for this purpose. The generator drive gear extends into the timing chest to mesh with the idler gear. The Sportster uses this generator charging arrangement until 1985 before converting to the much more reliable alternator charging system that did not perfect on the XL models until 1991.

Ignition

Now, I state the obvious. The spark plug must ignite the gas when both the pistons and valves position correctly relative to each other.

Modern Harley's started using a transistorized electronic ignition half way through 1978. It improved continuously until the present day when we have a total engine management system with its various sensors reporting information to the central computer known as the electronic control module (ECM), sometimes also called the electronic control unit (ECU) or ignition control module (ICU), to fire the spark plugs at the correct time relative to positioning of the valves and the pistons.

Unlike the mechanical circuit breaker, a stationary magnet sensor sitting in the front left-side engine casing reads cutaways in the modern 1999-present Twin Cam crank's left flywheel. The electrical pulses sent back to the ECM inform the computer about piston and thus valve location to ignite the spark plug at the appropriate time. The computer can even tell the compression stroke from the other three strokes by minute slowing of the flywheels due to building compression resistance on the rising piston dome.

The reader can now envisage the basic way in which the four-stroke engine operates and how all the moving parts are powered, coordinated, and timed to each other. The valves must be open or closed in time with piston location and direction in order to suck in the fresh intake charge, compress the intake charge, burn the intake charge to create heat-expansion pressure, and finally push the spent intake charge out the exhaust valve. The mechanical timing of all the related components is necessary for the point's ignition or the ECM as the case may be to time the spark ignition of the compressed air-fuel-mixture at the most opportune time to power the beast forward.

Year 1999 to 2001 Twin Cams had a secondary cam position sensor to assist in sending pertinent information to the ECM. It proved troublesome, unnecessary, and therefore discontinued. My personal theory is that it was too delicate to survive all the rear-cam-bearing destruction going on in 1999 and early 2000 and the relatively minor, but still important, other timing chest problems until major changes were instituted first in the 2006 Dyna. The timing compartment problems were:

1. An integral keyway cast into the 1999 rear cam drive gear sometimes sheared in its keyway groove in the end of the rear cam journal causing both correct ignition and cam timing to abort. This situation was corrected in late 2000 by splining the end of the rear cam journal to match with an inner diameter mating-splining of the rear cam drive gear mounting hole.
2. The rear cam-drive gear hold-down bolt's head sometimes *popped* off in 1999 from stress. This was corrected by making a new bolt that did not have weakening threading extend up to the underside of the bolt head; precision grinding of the thrust washer underneath the head of the hold-down bolt to ensure even pressure plus a new Loctite and tightening specification for the new bolt in 2000.

3. Disintegrating rear cam outboard support journal bearing in 1999 and early-2000. This was corrected in late 2000 with the introduction of a roller bearing kit.
4. The problematic inconsistent spring-loaded primary and secondary cam chain adjusters used from 1999 to 2006 corrected in the 2006 Dyna with consistent hydraulic-operated adjusters.
5. The fast-wearing, cracking, and sometimes breaking material used for the spring-loaded adjuster from 1999 to 2006 corrected in the 2006 Dyna with a durable nylon pad shoe.
6. Furthermore, the sharp-edge *silent* primary and secondary chains used from 1999 to 2006 that aggravated spring-loaded adjuster pad wear corrected in the 2006 Dyna with rounded roller timing chains.
7. Finally, the .875" diameter INA rear cam journal support bearings sometimes disintegrated but usually showed alarming rates of wear-movement in their engine casing housings from 1999 to 2006. This situation seems to have corrected beginning in the 2006 Dyna with the introduction of a .125" diameter increase of the rear cam journals as well as with an increase to 1.000" INA support bearings.
8. The oil pump also modified in the 2006 Dyna to increase feed pressure by 10% and scavenging return pressure by 23%. This change did not occur because of timing chest breakdown of component parts but to address oil blowby out of the air breather.
9. Furthermore, there were upgrades to the cam support plate to attempt addressing cam support journal end bearing situations ending with the elimination of actual bearings in favor of *parent material bearings* beginning in the 2006 Dyna, which I will be discussing at great length.
10. There were other timing chest problematic parts like stepped-cam lobes that had to do more with temporary bad production runs than with ineffective design.

Timing Spur Gears

All 1927 to 2000 timing chest gears except the crude helical distributor drive gears are spur gears, which are straight-cut. Mating spur gears as well as the distributor angled gear teeth are not in full contact with each other all the time, which is the cause of the noise they generate.

When at rest, the gear teeth may be in contact with each other to varying degree or not at all. As the drive gear powers it's mating gear there will be a sound generated variously described as clapping, slapping, or clattering. The mechanical term is backlash. Further compounding the problem is the expansion and contraction of their composition steel metal as the engine heats up with use and cools down when shut off.

The elimination of timing gears and the use of silent timing chains when correctly manufactured to the same specifications as on the original prototype Twin Cams are the biggest noise reducer. This is not to say that the transmission gears, the primary chain, and its sprockets do not contribute noise either. It is just that the timing gears are the biggest contributor of the three sources. I have already gone through the technologies that Harley-Davidson uses to make transmission spur gears quieter than ever before.

Interestingly, the primary system on the 2007 Big Twins amplifies the new noises emanating from the supposedly quieter six-speed transmissions even with ribbed inner bodies and the wet clutch set up requiring about a liter of cooling oil both help to dampen the din. Two steps forward, one step back will become a common theme.

Although the five-speed spur gears do generate noise, it seems to cancel somewhat through the oil and primary design. The new six-speeds have a different noise, particularly in fifth gear when not under load, as in cruising down the highway. The six-speed primary also has noise-dampening oil but for whatever reasons seems to transfer this new noise to the rider's ear. Perhaps it is just a different frequency. On the other hand, is it just a different noise than what the traditional rider expects? A clue is that the noise will decrease or disappear when the engine is under load, as in acceleration. H-D says all is normal. I will examine this in detail in Chapter X: *The Controversial Harley 6-speed Transmission.*

The Belt Drive

There is no real reason to digress into other EPA changes dictated by noise at this point but I find the subject fascinating because of Harley-Davidson design alterations forced by emissions reduction. I suppose I could connect rear drive chain noise with quiet timing chain noise reduction. In any case, I will proceed in my digressive ways.

American Iron Magazine readers have read my comments many times before that I feel the real reason, the Factory went to rear drive belt and pulley systems was to eliminate rear chain noise, which offended the emissions cops as early as 1980. Harley even experimented unsuccessfully in terms of reliability with primary belt drives during the same era with the first Shovelhead Sturgis models.

The type of single-row chain used on the older Harley rear drive is big, coarse, and noisy. They use rollers that rattle around and even sing at certain pitches. There is no dampening, oil-filled closet around them except during a few experimental FLT Shovelhead years.

However, primary systems using duplex chains suppress generated noise by a wide margin when compared to rear exposed chains. The appropriately named 1999-2006 TC88 silent cam chains are small and involve six plates aligned side by side to produce less noise than even the tempered and machined gear-cut technology utilized in the transmission.

The development of the Aramid fiber Kevlar rear belt drive not only satisfied the EPA police but turned out to be probably the most popular design change in the history of Harley-Davidson with its legions of loyal followers. Harley riders were so impressed with its reliability and longevity that they referred to the belt drive as bulletproof. Of course, the belt drive was not bulletproof since a rock between belt and pulley could easily puncture the belt. Even a stone punctured belt could easily survive another 20,000 miles to 50,000 miles before requiring replacement. H-D developed a repair kit for fixing rear belt drive breakage back in the early nineteen-eighties but soon discontinued it for lack of sales. I carried one around for years for myself and my riding buddies. Then, I left it for sale for over a decade on the wall in my bike shop. It finally disappeared somewhere but I know one thing; it never repaired a broken rear belt.

As I have discussed at length, Twin Cam models had some teething problems resulting from large-volume manufacturing that was not evident in the prototype test bikes even after one hundred thousand miles of testing on individual bikes, so I do not have to go through that stuff again except for the recurring problems.

Let's go back to the Shovelhead and Evolution timing gears and all the effort that the Factory went through over twenty-two years in progressively quieting them. I will say one thing for Harley; it went down fighting making every little improvement possible before acquiescing to a major change in engine design.

Color-Coded Cam Gear Sizing

Harley has seven different-size color-coded cam gears for 1989 and earlier with another seven color-coded different sizes for 1990 to 2000 Evolution motorcycles. Why the different sizes? Three gears mesh together in all 1970 to 2000 Evolution 1340cc models. They are the breather, the pinion and the cam gear located in the timing (nosecone) cover just below the carburetor. Only the steel pinion gear and the steel cam gear are color-coded as the breather gear is a very durable plastic and just goes along for the ride. It makes no noise because it is not metal.

The pinion gear is driven by the flywheels and transfers the rotating motion to both the breather gear and the cam gear. The breather scavenges oil from the bottom end compartment to send it back to the timing chest compartment on its way to the return side of the oil pump. The cam gear rotation powers the cam lobes to open and close the valves via the push-rods and rocker arms.

The pinion and the cam drive gears are positioned in opposing holes in the engine case and the attached timing cover. The breather gear sits in its own hole but must be positioned correctly to open its aperture as the pistons begin to descend since it meshes with and is driven by the pinion gear via the cam gear.

Manufacturing tolerances are precise for mass production purposes but not necessarily for an individual engine. The holes that support the gears are not always in exactly the same spots. They may vary by a few thousandths of an inch. When the same size exact mating gears are installed in seemingly identical engines, some will mesh properly; some will fit too tightly with each other, and some will fit too loosely.

- If they fit too tightly, the motor will whine and parts will wear out prematurely or in extreme cases, cause the gears to work against them and may even break.
- Too loose a fit and the motor will clatter, again resulting in adverse wear.
- In terms of parts longevity, the tight gears will wear out first but this doesn't mean that too loose is acceptable. The mechanical term for this is backlash. If there is too much backlash, the result will be a click that turns into a clatter as the rpm's go up. More specifically, as Andrews Products Inc. relates, "Whenever the roller follower on a cam lobe passes the maximum lift point, the forces on the cam drive gear tooth changes direction. If more than .002 inches backlash is present between the cam and pinion gear, this directional change of force will result in an audible click as the backlash moves from the backside of each gear tooth to the front side." [1]

The engine heating up and cooling down will cause tolerance changes anyway, right? Yes, it will. This is another reason tolerances must be fit a certain way when this fitment of color-coded gears is done when the engine is cold. The proper gear clearances will give a slight whine when the engine is hot and may give a slight clatter when cold. The color coding anticipates tolerance changes with heat expansion. The seven different color codes for 1984 to 1989 are orange (the smallest), white, yellow, red, blue, green, and black (the largest). Evolution pinion gears for 1990 to 2000 use the same seven colors but they represent different measurements. For example:

A 1990 to 2000 Evolution white color-coded pinion gear has a diameter of the gear face of 1.4846" to 1.4849".

- A 1984 to 1989 Evolution white color-coded pinion gear has a diameter of 1.4745" to 1.4751".

- These diameters are really a range of sizes and each has color identification. The color codes, by the way, are idenrified by a splash of paint on the gear face of the pinion and cam. It is an easy way to identify different-size gears rather than go through a laborious measuring process that we had to do in the old days, that is now done by Mother Harley for one and all.

The main difference is that the 1984 to 1989 color codes each span a full six-thousandths of an inch (.006" or .152mm)) while the 1990 to 2000 color codes each span only three-thousandths of an inch (.003" or .076mm). Therefore, the early graduations are .001" (.0254mm) apart while the later ones are graduated by .0005" (.0127mm). The Noise Cops were on the case making Harley get quieter and more precise.

Grooved Gear Identification Faces

1. Pre-1976 cam gears have no identification groove cut in its outer face. These are not interchangeable with 1977 to 1989 cams, as the teeth were cut with a non-precision North American standard measurement that will not mesh properly with post 1977 precision cuts.
2. A single groove is cut into the cam gear face to delineate a precision cut gear from late 1977 to 1989 with 6-gradations totaling .006" (.152mm).
3. A 1990 to 2000 Evolution cam gear outer face has two grooves cut into it for easy identification with 6-gradations totaling .003" (.076mm).
4. Shovelhead late-1977 to 1985 cams cannot be interchanged with 1984 to 1989 Evolution cams, even though the gear face tooth cuts are the same. The Evolution head requires a much different cam lobe profile than the Shovelhead. Evolution lobes are higher and narrower than their Shovelhead counterparts.

Aftermarket Cams

Most aftermarket late-Shovelhead and Evolution cams are color-coded in a red dimension or diameter range that, in most cases, will fit pre-1989 or post-1990 engines simply because it is the middle compromise measurement. However, backlash should be checked and if not satisfied, changing pinion gears to a larger or smaller size will resolve a fitment situation.

Therefore, if installing a high-performance cam or stock cam, for that matter and a severe whine ensues, simply install the next size smallest pinion gear to loosen the fitment gear-interaction tightness. If the opposite occurs with clattering, just install the next largest size pinion gear. This is crude but it works satisfactorily but unlikely perfectly. Why change the pinion gear and not the breather or cam gear?

The pinion gear is the easiest to change.

1. It is less expensive than the cam gear.
2. The breather gear is plastic and not color-coded and thus has no specific measured cuts. There is no load on the breather gear and thus no backlash of consequence.

Don't let color coding fitment psych you out. It is just a refinement to eliminate whining tightness and clattering looseness. Harley-Davidson's ran fine for 70-years without specific fitment specifications before the advent of noise pollution concerns.

Evolution Timing Gear Fitment Specifications

Pinion Gear Sizing Late-1977 to 2000

Pinion Gear	Color code	Pitch diameter	Year of use	Engine
24040-78	Orange	1.4751-1.4756	Late-1983	Shovelhead
24041-78	White	1.4745-1.4751	Late 1977-1983	Shovelhead
24042-78	Yellow	1.4737-1.4745	Late 1977-1983	Shovelhead
24043-78	Red	1.4729-1.4737	Late 1977-1983	Shovelhead
24044-78	Blue	1.4721-1.4729	Late 1977-1983	Shovelhead
24045-78	Green	1.4715-1.4721	Late 1977-1983	Shovelhead
24046-78	Black	1.4710-1.4715	Late 1977-1983	Shovelhead
24040-78	Orange	1.4751-1.4756	1984-1989	Evolution
24041-78	White	1.4745-1.4751	1984-1989	Evolution
24042-78	Yellow	1.4737-1.4745	1984-1989	Evolution
24043-78	Red	1.4729-1.4737	1984-1989	Evolution
24044-78	Blue	1.4721-1.4729	1984-1989	Evolution
24045-78	Green	1.4715-1.4721	1984-1989	Evolution
24046-78	Black	1.4710-1.4715	1984-1989	Evolution
24040-90	Orange	1.4850-1.4853	1990-1992	Evolution
24041-90	White	1.4846-1.4849	1990-1992	Evolution
24042-90	Yellow	1.4842-1.4845	1990-1992	Evolution
24043-90	Red	1.4838-1.4841	1990-1992	Evolution
24044-90	Blue	1.4834-1.4837	1990-1992	Evolution
24045-90	Green	1.4830-1.4833	1990-1992	Evolution
24046-90	Black	1.4826-1.4829	1990-1992	Evolution
24040-93	Orange	1.4850-1.4853	1993-2000	Evolution
24041-93	White	1.4846-1.4849	1993-2000	Evolution
24042-93	Yellow	1.4842-1.4845	1993-2000	Evolution
24043-93	Red	1.4838-1.4841	1993-2000	Evolution
24044-93	Blue	1.4834-1.4837	1993-2000	Evolution
24045-93	Green	1.4830-1.4833	1993-2000	Evolution
24046-93	Black	1.4826-1.4829	1993-2000	Evolution

The gear sizing is very precise in tenths-of-a-thousandths of an inch (1/10 of .001"). The late 1977 to 1989 precision gear sizing had a wider range in fitment size of 6-tenths of a thousandths of an inch (6/10 of .001" or .0006") while 1990 to 2000 pared this fitment in half for even more precise matching of mating parts (3/10 of .001" or .0003") although the measuring is in North American standard. In countries using the precision system like all those in Europe, these measurements would be in millimeters (one-thousandths of a meter) Pre-late 1977 gearing is in North American standard sizing. This alone does not indicate less precision but the fact that gears were ground imprecisely does. In these early years, hardening further complicates precision because the process will cause high and low spots. Newer technology allows grinding after hardening to allow more precise fitment.

Cam Gear Sizing Late-1970 to 2000

Part Number	Color code	Size	Years of use	Engine Type
25523-70	None	Standard	1970-early 1977	Shovelhead
25527-81A	Orange	2.7324-2.7334	Late 1977-1983	Shovelhead
25528-81A	White	2.7334-2.7344	Late 1977-1983	Shovelhead
25529-81A	Yellow	2.7344-2.7354	Late 1977-1983	Shovelhead
25530-81A	Red	2.7354-2.7364	Late 1977-1983	Shovelhead
25531-81A	Blue	2.7364-2.7374	Late 1977-1983	Shovelhead
25532-81A	Green	2.7374-2.7384	Late 1977-1983	Shovelhead
25534-81A	Black	2.7384-2.7394	Late 1977-1983	Shovelhead

It was common to switch the cam gears to obtain the desired sizing fitment from 1977 to 1983. From1984 to 1989, the practice changed to replacing the complete camshaft with in conjunction with a timed-cam gear for correct fitment. From 1990 to 2000, the preferred methodology was to replace the camshaft with timed gear and a pinion gear in matched sets. This methodology also reached back to 1984 for those inclined.

Camshaft and Cam Gear Assembly Sizing

Part Number	Color code	Gear Size	Years of use	Engine Type
25536-84	Orange	2.7324-2.7334	1984-1989	Evolution
25537-84	White	2.7334-2.7344	1984-1989	Evolution
25538-84	Yellow	2.7344-2.7354	1984-1989	Evolution
25539-84	Red	2.7354-2.7364	1984-1989	Evolution
25544-84	Blue	2.7364-2.7374	1984-1989	Evolution
25545-84	Green	2.7374-2.7384	1984-1989	Evolution
25546-84	Black	2.7384-2.7394	1984-1989	Evolution

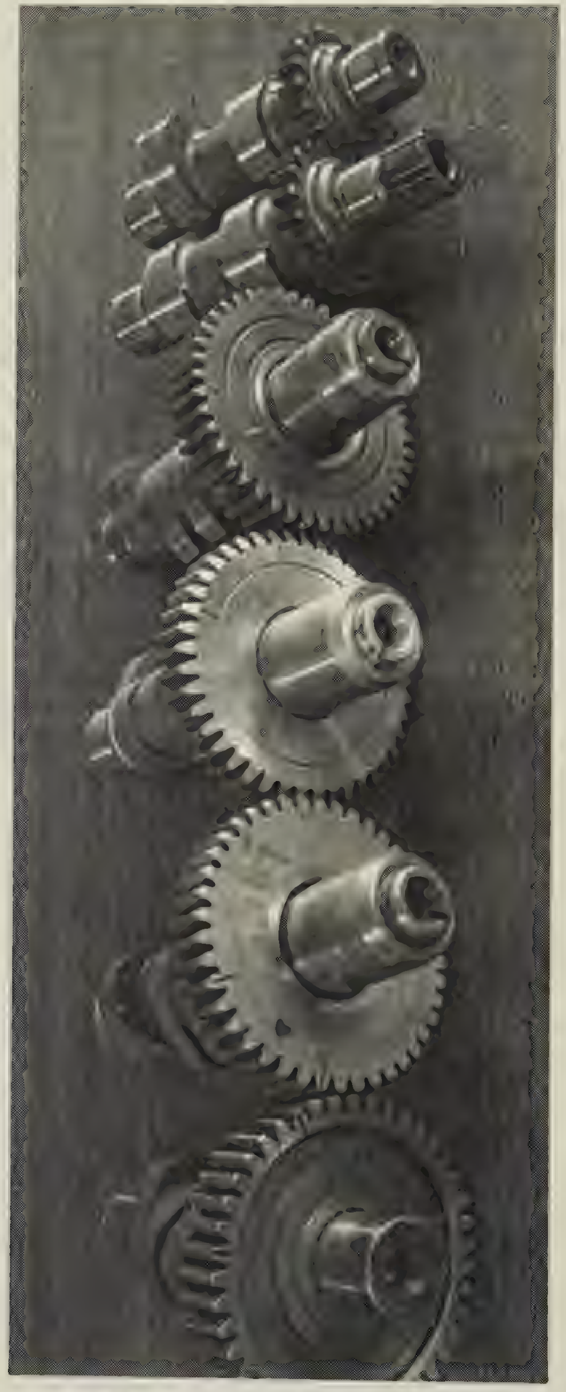
Camshaft with Gear & Pinion Gear Matched Sets

Part Number			Years of use	Engine Type
24582-83A	Matched gears	Matched gears	1984-1987	Evolution
24582-88	Matched gears	Matched gears	1987-1989	Evolution
24581-88 [1]	Matched gears	Matched gears	1987-1989	Evolution
24581-90 [1]	Matched gears	Matched gears	1990-1992	Evolution
24582-90	Matched gears	Matched gears	1990-1991	Evolution
24583-92	Matched gears	Matched gears	1992	Evolution
24581-93 [1]	Matched gears	Matched gears	1993-2000	Evolution
24586-93	Matched gears	Matched gears	1993-2000	Evolution
24587-95 [2]	Matched gears	Matched gears	1995-1998	Evolution

From 1977 to 1983, it was common to switch the cam gears to obtain the desired sizing fitment. From1984 to 1989, the practice changed to replacing the complete camshaft in conjunction with a timed-cam gear for correct fitment. From 1990 to 2000, the preferred methodology was to replace the camshaft with timed gear and a pinion gear in matched sets. This methodology also reached back to 1984 for those inclined. I must say that sometimes H-D does not appear concerned about the customer pocketbook when a simple gear change will do the trick. On the other hand, if the Factory performs all the measurement and fitment concerns, it can easily be argued that there are labor savings and the customer is assured of a correct fit.

[1] California only

[2] EFI



Harley-Davidson Big Twin Camshafts 1948 to 2006

Pictured are cams from the Panhead era up to year 2006. The bottom cam is used in Panheads and Shovelheads up to 1969. Second from the bottom is the first *nose cone* cam used in Shovelheads from 1970 to circa 1976. These first two cams are not interchangeable because of the different size outboard journal ends. The 1970 to 1976 outboard journal is thicker and longer than on its predecessor earlier cam. The spur gears are cut with North American standard measurement teeth with no attempt made to mate them precisely with interacting gear teeth in an effort to reduce noise. The third cam from the bottom, with a single circular line machined into its gear face is the first H-D cam with precision-gear-cut teeth. These are not interchangeable with the 1970 to 1976 timing gears because of the differently cut teeth. Many Harley owners and mechanics have matched post-1976 precision gears with pre-1977 standard ones over the years, causing rapid gear teeth wear and broken teeth that are ground up and sent through the engine to wreak further destruction. This first precision high-contact-ratio gear was used up until 1989 but the pressed-in camshaft for the 1977 to 1984 Shovelheads is dramatically different from the 1984 to 1989 Evolutions that share the same precision cut cam gear teeth. Shovelhead cam lobes have much more duration than their Evolution counterparts do. Evolution emissions controls dictate very little overlap between engine cycles and thus much less duration. However, Evolution camshaft lobes have much more lift than the Shovelhead's. H-D lessened the valve angles in Evolution and Twin Cam engine's from the predecessor engines, which angled the valves at a wide slant to perpendicular. This Evo-Twin Cam valve angle reduction allows much higher cam lifts because it lessens valve-to-valve guide side loading forces. These 1977 to 1989 cam gears come in seven different diameters spanning six-thousandths of an inch (.006") in .001" increments so that they can match more precisely with their mating breather and pinion gears. Pinion gears also come in different sizes. This proper fitment reduces gear lash and therefore noise. The two circular lines (third from the top) delineating 1990 to 2000 gear faces differentiate them from the earlier gear faces. They also have seven different diameters but only span .003" in half-thousandths-inch (.0005") increments. Noise was becoming a big issue as the Factory struggled to make the timing gear interactions quieter. The top pair-of-cams is for 1999-2006 TC88 engines. While they look the same, year 2007-to-present TC96, TC103, and CVO 110 cams, have a different sprocket, camshaft, and cam lobes. TC 88 cams are 1-piece while 2006 Dyna and all 2007 to present Twin Cam cams are 5-piece, pressed together to allow different metallurgy and hardening for different tasks. In the quest to meet tightening EPA noise pollution regulations, Harley abandoned gear-driven timing gears in use up to the advent of the Twin Cam for supposedly quieter chain-driven ones utilizing sprockets instead of gears. Two camshafts with two lobes on each evolved in order to keep the outside of the engine looking traditional and therefore much the same as previous models.

H-D Engine Design Forces

The pollution cops pressured Harley to alter the basic engine design away from gear-driven timing gears. Reduction but not elimination of the valve train noise is the best-case scenario. Harley chose to use a supposedly quieter timing chain-drive system to replace the timing gears.

Engine shape would have changed too much if there were only one camshaft with four cam lobes driven by a timing chain, sitting above the powering pinion shaft. Therefore, two camshafts with two cam lobes each angled over to either side slightly above the driving pinion shaft became the chosen option. The solution of choice necessitated that previous gears now became sprockets connected by a timing chain from the pinion shaft to the rear cam and a second timing chain connecting to the rear cam and driving the front cam.

H-D also resolved another longtime nagging efficiency problem with the two-cam design, pushrod angularity.

Pushrod Angularity Reduces with More than One Cam

Exhaust pushrods have always angled too severely away from the 1936 to 2000 centrally located cam lobes to actuate exhaust-valve rocker arms at the extreme front and rear positions in the engine. Now, all four pushrods sit pretty much under their respective rocker arms. This relieves much former stress on the two outside exhaust hydraulic lifters.

Of course, the V-Twin Flathead engines beginning in 1929 and ending in 1973 as well as the 1957-to-present Sportster engines utilize four separate camshafts with one valve-actuating lobe each. This is a much better system than even the two-cam methodology from a pushrod angularity point of view. Each cam lobe is directly under its valve train.

Design Forces: Emissions and Rider Acceptance

H-D design has two driving forces.

1. One is ever-increasing emission dictates.
2. The other is consumer acceptance, always driven by traditionalist and nostalgic perception of what the look must be.

The first force is irrefutable. H-D must meet emissions demands. The second force works within these confines to find an acceptable design to the riding public.

I have discussed existing technology that is unacceptable to traditionalist H-D riders that would resolve these issues. But even they will not be acceptable for long as they may not accommodate the alternative clean fuels that will begin to replace oil sometime in the next few decades when global warming becomes the greatest challenge to humanity's survival.

Before I get too deep into rising ocean levels and melting ice packs, the Twin Cam 88 engine with its timing chains necessarily replaced its predecessor Evolution gear drive to resolve some 1999 noise pollution issues. However, this is only one step on a long stairway of change.

One Mechanical Change Always Leads to Another

As always, one change always leads to a succession of others.

The timing chains need proper tension. Spring-loaded adjuster shoes achieve this.

1. The outboard cam journals require quieter support bearings. Ball bearings for the 1999 outboard cam journals are the result.

Something else occurred between prototype design models and the transition to mass production of the Twin Cam motorcycle. As the reader knows, I viewed the prototype Twin Cams in Milwaukee about nine months before their introduction to the public.

They were indeed quieter. My mass-produced 1999 Twin Cam Road Glide is not. While we service Flatheads, Knuckleheads, Panheads, Shovelheads, Evolutions, and Ironheads at Heavy Duty Cycles in Toronto, we also do a large volume of work on Twin Cams. Evolution engines are very much quieter than predecessor H-D engines. The primary objective in Twin Cam design is to eliminate or reduce Evolution engine noise.

In my experience, some Twin Cam engines are quieter than the Evolution engine while some are about the same, and some are louder. This perception is not the way it is supposed to be.

The Performance Problem with Timing Chains

From a performance perspective, there is a big quandary on 1999 to 2006 Twin Cams excepting the 2006 Dyna with:

1. There is a loose fit between the four cam-drive sprockets and the two silent timing chains.
2. The tension-strength of the spring-loaded chain tensioners may allow cam-timing variations.

Sloppy Parts Fitment leads to Sloppy Timing

The loose sprocket-to-timing-chain fit on all Twin Cams allows cam timing to waiver by as much as four degrees. On the stock engine, this is not noticeable because there is no comparison to gauge it. One only has to look at these sprockets to see that exact timing is impossible. It should not happen in a perfect world where this can rob the engine of torque and horsepower. In addition, it certainly does not happen with a properly fitted gear drive.

Furthermore, if installing performance valve springs, they will dominate the weaker adjuster tensioner springs on 1999 to 2006 Twin Cams and will add extra pressure to the 2006 Dyna and all 2007-to-present hydraulic adjusters. As a result, timing can be off as much as an additional five degrees on early models using performance valve springs.

Also, from a performance perspective, there are concerns with 2006 Dynas and all 2007-to-present Twin Cams with:

1. The loose fit of the new design cam-drive sprockets and the new-style timing chains.
2. Moment Arm torsional stress to the rear-cam-outboard-journal parent-material-bearing in the cam-support-plate. The 22 ½^0 offset primary (outboard side) timing chain exerts *Moment Arm Force* on the parent-material-bearing hole that may oblong it over time. I will describe Moment Arm Force in more detail further on in this chapter. However, I really get into this fascinating subject in Volume II: *Performancing the Twin Cam*, in Chapter II: *Repairing the Achilles Heel.*

What is a Parent Material Bearing?

The 2007 Model Year Technical Forum produced by Harley-Davidson University listing changes to various parts and/or components is very educational. It discusses the new cam-support-plate's parent material bearings. Well if I ain't the dumb duck! I had never heard of a parent bearing before. Off, I go trying to figure out what a parent material bearing is. I mistakenly thought they must mean a plain bearing, which is an insert similar to a bushing but made of a harder material.

I taught apprentice mechanics for years so they could become licensed motorcycle mechanics. I never taught about parent material bearings. Into my reference books I go, looking for this mysterious bearing with no luck. Now I approach Harley-Davidson service managers in dealerships and their advisors, the regional service reps to no avail. No one knows what this type of bearing is.

Onto the Internet I go. It leads me further astray towards plain bearings and double row bearings. Finally, out of frustration, I resolutely deal with the problem and take my new 2007 FLHXI apart to see for myself. I cannot believe what I see? A parent material bearing is simply a hole in the *parent material* cam-support-plate that supports the outboard cam journals. There is no traditional ball or roller bearings supporting the outboard cam journals.

Valve Train Inertia and Momentum

Performance springs have a higher seat pressure in order to ensure the valves follow the dictates of the cam lobes. The valve spring pressure pushes back on the valve train to make sure the tappet roller follows the precise directions of the cam lobe.

Higher lift cams push the valves out farther into the head to allow more air and gas into the cylinder. Longer duration cams keep the valves open longer for the same purpose of allowing more fuel in. Longer duration is usually combined with higher lifts both for performance reasons but also to combat the physical principles of inertia and momentum.

- Inertial forces encourage an object to stay in the same plane doing the same thing. For example, if an object is at rest, inertia describes the predisposition for the object to remain at rest and resist movement.
- If already moving, an object will seek to stay in a uniform motion unless acted upon by another outside force.
- In short, an object wants to keep doing what it is doing unless another force modifies or changes its behavior.
- Momentum force dictates that a moving object keeps going on the same plane.
- This may sound the same as inertia, but it describes more exactly the property that a moving object has due to its mass and motional force.

These forces apply to every movement in an engine. Specifically, in this case I will examine how these forces apply to the tappet roller and thus the whole valve train following the cam lobe.

First, let me set up a scenario where the cam lobe has lots of lift but not much duration relative to the lift just like Evolution and Twin Cam cam-lobes. The egg-shaped cam lobe shape becomes more pointed.

The mechanical reason the lift can be higher is because of a reduction in valve angles from Shovelhead and predecessor bikes reduces side loading of the valve against the valve guide.

1. The emissions reason for higher lift with less duration is to contain pollutants in the combustion chamber.
2. A positive for higher lift with less duration is this will produce more torque for heavier bikes especially at lower speeds.

However, the forces of inertia and momentum come into play:

3. Inertial forces will not want the roller to change direction to follow the cam lobe over its pointed peak.
4. Momentum will encourage the roller to *fly* off the end of the pointed lobe in the same plane of movement.
5. The stronger seat pressure valve springs attempt to force the roller to follow the cam lobe profile exactly with no dalliance. The valve springs become the force to alter inertia and momentum force. Cam manufacturers usually assist this process by combining duration with lift to give a more rounded profile to the cam lobe at its highest point.

As I pointed out earlier, stronger springs may further alter the cam timing in a spring-tensioned, timing chain Twin Cam engine. Timing may be around what it is supposed to be or it may slightly advance or retard. There is no predictability. I am sure a mechanical engineer could plot where and how much the cam timing would vary, because the forces of inertia and momentum combined with spring tension will give the information required. For us to figure it out exactly, I do not think so.

Therefore, the result is that the spark plug may not always be igniting the fuel at the optimally designed time. The pistons may not be at the most advantageous position to deliver engine efficiency and its compatriot performance.

Performance Valve Springs

Early in 1999, performance mechanics made the discovery that when installing high-performance cams and higher-seat-pressure valve springs in the TC88, performance expectations were not always forthcoming. If jumping forward to 2007, it is also interesting to note that all the performance horsepower one would expect from the eight extra cubic inches in the TC96 are also not forthcoming, as one would expect although for different reasons. I will explore this at length in Volume II: *Performancing the Twin Cam,* Chapter VII*: Horsepower and Torque.*

As I have discussed, the reason heavier seat pressure valve springs are installed in an engine is to make sure that the valve train follows the instructions laid out by the cam lobe profile. In other words, the valves open and close when instructed. This is necessary to prevent the dreaded valve float that robs horsepower and can demo an engine.

Valve Float

Valve float occurs when the valve(s) decides to hang around in the combustion chamber after the cam lobe retreats to a closing position. High rpm or a wild cam profile with all lift and no duration can easily confuse the valve as the properties of momentum and inertia come into play. At the peak of the cam lobe, the valve will want to keep going to open farther under these conditions. It may open farther or fibrillate in no man's land until the valve springs take charge and force the errant valve back to its valve seat.

Valve Bounce

Valve bounce, the lesser-known cousin of valve float, occurs when the valve hits its mating seat at high rpm. The valve tends to bounce off the seat, causing much the same problems as float. Valve bounce became a bigger issue when H-D introduced hardened valve seats and valve faces in 1981-1982 because of the banning of the octane additive lead. The new octane formulas do not have the cushioning effect of lead. Therefore, replacement of the softer valve seats with harder ones became necessary.

Heavier valve springs will also correct valve bounce. Valve spring pressure to an engine's potential rpm range and the profile of the cam must closely match for best results.

- Heavier seat pressure is required to ensure the valve train and valve follows the contour of the cam lobe.
- However, heavier seat pressure will cause some extra stress on valve train components. Therefore, excessive seat pressure for a particular cam lobe profile can exacerbate wear.

S&S to the Rescue

The venerable S&S Cycle, Inc. (www.sscycle.com), one of the most innovative aftermarket companies is again improving existing engine design. S&S has figured out something that has bothered me as well as many others, for a while now. First, we need background information.

Comparing Cams

I am sitting here in year 2000 with five sets of cams and comparing them.

1. First is the 1999 stock Harley cams with the less-than-desirable cast-in keyway design.
2. Second is the improved 2000 stock Harley cams with the upgraded spline shaft replacing the 1999 keyway.
3. In addition, rounding out the comparison are Andrews (www.andrewsproducts.com), Crane (defunct as of 2009 but now available as an S&S product), and Screamin' Eagle (www.harley-davidson.com), sets with spline shafts. The aftermarket reportedly makes Screamin' Eagle (S.E.) cams for Harley-Davidson.

Quality aside, the disadvantage of all the above cams utilizing cam sprockets with timing chains is well-documented in other parts of this section particularly when using performance valve springs, which many times are stronger and dominate the chain-adjuster springs, which affects cam timing.

Andrews, Crane, and S.E. cams produce okay horsepower gains for mild hop-ups when using the appropriate team of support parts, which include stock Harley valve springs or very mild seat pressure performance springs, notwithstanding the wandering cam-timing situation. Stock factory cams are hamstrung by emissions controls, so good power gains are severely restricted through no fault of Harley-Davidson.

I am comparing these five sets of cams to the new S&S gear-driven set. The obvious thing that strikes the viewer first is that all the aftermarket cams including the S.E. ones appear to be very much superior to the stock Harley cams in metal composition, machining, and finishing. It bears mentioning that there is nothing wrong with the Harley cams, except as noted in Chapter II: *1999 to 2000 Teething Problems*. It is just that the aftermarket cams take quality to a higher level. In fairness, marketing also influences their look since riders buy them and therefore get to inspect them whereas H-D cams are pre-installed.

The S&S Gear Drive Solution

Cam Lift and Duration

Stock valve lift of the first H-D TC88 dual cams is .473” and duration is 216-degrees on intake and 220-degrees on exhaust for both carbureted and EFI models. Some really early models came with a .490” lift although I have never seen a set. TC96 cams have the intake duration of 196-degrees and exhaust duration of 220-degrees. TC96 intake valve lift is .471” and the exhaust valve lift is .474”.

Twin Cam stock Camshaft Specifications

Grind	Valve	Timing*	Duration*	Valve Lift*	Cam lobe lift	Overlap
2008-to-present 96c.i	intake	-12/30	198^0	.484”	.298”	
	exhaust	38/04	222^0	.484”	.298”	0^0
2007 all models 96c.i	intake	-09/25	196^0	.471”	.290”	
	exhaust	39/01	220^0	.474”	.292”	0^0
2006 Dyna EFI 88c.i	intake	02/34	216^0	.473”	.291”	
	exhaust	36/06	220^0	.473”	.291”	8^0
1999 carbureted 88c.i	intake	-02/38	216^0	.473”	.291”	
	exhaust	36/-04	220^0	.473”	.291”	0^0
1999 EFI 88c.i	intake	02/34	216^0	.473”	.291”	
	exhaust	36/06	220^0	.473”	.291”	8^0

*Cam timing, valve lift and duration specifications are measured from .053” off the baseline heel of the cam lobe. Valve lift is a multiple of the rocker arm ratio (1.625) and the actual cam lift.

These figures will be the baseline for comparison measured from .053” off the baseline heel of the cam lobe. Each year brings new manufacturers, grinds and cam specifications. Lifts are valve lifts. Actual cam lobe lift multiplies by the Twin Cam 1.625 rocker arm ratio to achieve the valve lift of the particular camshaft. For example, a 1999 TC88 camshaft has a cam lift of .291”. Multiply the cam lift of .291” by the rocker arm ratio of 1.625 to achieve a valve lift of .472875”, which rounds to .473”. See Volume II: *Performancing the Twin Cam*, Chapter IV: *Cams, Cams, Cams* for everything the reader wants to know about cams and then some.

Twin Cam Valve Seat Spring Specifications

Engine	Valve spring type	Spring closed	Spring open	Free length
TC88	Dual coil cylindrical outer spring	72-92lbs @ 1.751”-1.848”	183-207lbs @ 1.282”-1.378”	2.105”-2.177”
TC88	Dual coil cylindrical inner spring	38-49lbs @ 1.577”-1.683”	98-112lbs @ 1.107”-1.213”	1.926”-1.996”
TC96	Single coil beehive spring	135lbs @1.850”	312lbs @ 1.300”	2.325”

Metric Equivalent Specifications

Engine	Valve spring type	Spring closed	Spring open	Free length
TC88	Dual coil cylindrical outer spring	33-42kg @ 44.5-46.9mm	83-94kg @ 32.6-35.0mm	53.47-55.30mm
TC88	Dual coil cylindrical inner spring	17-22kg @ 40.1-42.8mm	44-51kg @ 28.1-30.8mm	48.90-50.70mm
TC96	Single coil beehive spring	61.2kg @47.0mm	141.5kg @33.0mm	59.10mm

[1] In 1999, the Twin Cam continued to use the Evolution valve springs instituted in 1984. These dual cylindrical shaped valve springs (18201-83 outer and 18202-83 inner), one inside the other hold each valve closed on early Twin Cams up until 2003 and early 2004.

[2] A single beehive shaped valve spring (18245-02), operates the closing of each valve on later Twin Cams from circa 2004 on. Thus this valve spring bridges both late TC88 engines as well as the TC96, TC103, and CVO 110 engines. The valves used with the beehive springs also have narrowed diameter valve stems reducing valve and thus valve train weight. Anytime valve train weight reduces, two beneficial results emerge; the engine can rev higher since there is less mass to move up and down; secondly a lower seat pressure will perform intended functions since there is less weight once again, to impede the valve's return to its seat. Less weight combining with an effective less seat-pressure-spring reduces valve seat slam and thus wear from the returning valve.

[3] Early dual cylindrical springs have an acceptable specification range while the later single beehive spring is much more precise.

[4] Valve spring float is different from but can cause valve float. This is known as harmonics where the spring-coil begins to behave erratically instead of applying consistent unwavering pressure to return to the closed position. If a valve spring (set) has even dimensions and pressure capability throughout its length harmonics can and often will occur especially with high rpm riding. To counter valve spring harmonics on dual spring sets, the inner spring normally counter winds to the outer to combat fibrillation. The different sizes of inner and outer also combat this untoward spring movement away from designed compression and extension under duress of performance riding and/or cam design. The springs may also progressively wind, whereby coils are closer together at one end than on the other spring to prevent harmonics from impeding intended travel and function. The single beehive spring progressively changes shape from narrow on the top valve collar to wide on the bottom lower collar to combat untoward harmonics. The changing diameters of the coils have progressively changing physical properties that battle fibrillation from gaining a foothold and expanding their counter-surging characteristics.

[5] Common dual seat pressures for Crane springs, as an example is 155-lbs seat pressure for milder performance cams and 175-lbs pressure for more demanding cam profiles.

Andrews Cams

At the time of writing in the early TC88 years, Andrews offers lifts ranging from .490", .498", .490", .510", .550", .560", .590" and to .640" lift and durations from 220⁰ degrees to 276-degrees.

Crane Cams

Crane has lifts ranging from .505"; .570", .600" and .619" lift with durations of 226⁰ to 260-degrees. Crane is now defunct as of 2009 but many of their fine products are now available from S&S Cycles, Inc.

Screamin' Eagle Cams

Screamin' Eagle has lifts ranging from .510" intake/.483" exhaust, .508", .538", .550", .569", .579", .609" to .635" lift with durations of 234⁰ to 269-degrees.

S&S Cycle, Inc. Cams

The S&S gear-driven cams have lifts that start at .510" lift then go to .570" lift and continue to .585", 625", .640", and to an incredible .675" lift with longer durations from 238⁰ to 275-degrees.

As the years progress, a much wider variety of both cam manufacturers and cam lifts/durations continuously evolve. Consult with your local dealer for aftermarket manuals or the Internet for the spectrum of availability. It is extremely important to match cam profiles with other performance work and valve spring seat pressures as well as the type of performance desired within an acceptable rpm riding range. I guess, I just advised consulting with a non-biased and knowledgeable performance mechanic for recommendations for *your* needs and wants. This will involve answering questions so the mechanic can get a feel for what you are after.

The Superstars

Unless I am missing something, I do not see how it is possible to run anything but the gear-driven cam sets when heavy seat pressure valve springs are required for accurate cam timing. Furthermore, to develop a truly reliable and fast Twin Cam engine, headwork, compression increases, and bigger cubic inches all require coordinated modified cams and therefore the recommended heavier valve springs. Make no mistake; stronger springs are very necessary with the higher lifts.

I think high lifts and matching springs will play havoc by prematurely wearing out the TC88 1999 to 2006 timing chain adjusting parts. Furthermore, the cam timing will alter by as much as five more degrees beyond the initial four degrees.

The later Twin Cam engines (2006 TC88 Dyna Glide and 2007-to-present TC96, TC103, and CVO 110) with hydraulically adjusted timing chains control timing variances beyond the initial loose fit sprocket timing inconsistency much better. However, they still have to deal with more stress from stronger valve springs over time that gear drives have no problem with.

1. The cams offered by the manufacturers that use .483", .490", .505", and .510" lifts can use the stock valve springs, but those with the .538", .550" .560", .570", and .600" and higher valve lifts must use increasingly stronger performance springs. The mechanic could probably get away with the .538" valve lift and maybe the .550" lift cams without performance valve springs. However, I advise using the manufacturer recommended matching springs to control valve float and ensure there is no valve spring coil binding.

Again, the higher the lift, the more seat pressure is required.

Colliding Camshaft Lobes

The mating cam lobes on the two respective rotating cams come close to each other for an instant every 360-degrees. Cam lobes from each of the cams can interfere with each other and collide with higher lifts. S&S first resolved this engineering problem. Interference between cam lobes is not an issue because S&S reverses the rotational direction of the rear cam. The rear high-lift cam lobes are out-and-out pointing in different directions than any of the stock rear cams in order to maintain clearance with other moving parts. With the cam lobe reversal blueprint, the valves still open and close as originally designed.

Clearancing *Chain Drive* Hi-lift Cams

Chain drive cam designers initially resolved high-lift timing-chain cam-lobe interference issues in the very beginning of the Twin Cam's introduction without reversing the rear cam orientation. As I have said, Twin Cam camshaft lobes rotate beside each other creating a potential interference problem when increasing cam-lobe lift every 360-degrees when the highest point of the respective mating lobes pass each other. Hi-lift *gear drive* cams reverse the rear cam lobe rotation while *chain drive* cams change the cam lobe base-circle dimensions to allow higher lifts.

First, a little math; to get the valve lift we multiply the cam lobe lift by the rocker arm ratio, which is 1.625 to get the valve lift. In this example I will use a cam lobe lift of .291" (.291" cam lobe lift x 1.625 rocker arm ratio = .473" valve lift).

Next, to get cam lobe lift from valve lift simply divide the valve lift by the rocker arm ratio (.473" valve lift ÷ 1.625 rocker arm ratio = .291" cam lobe lift).

I will use .650" valve lift cams, which have a .400 cam lobe lift in this Twin Cam chain drive example (.400" cam lift x 1.625 rocker arm ratio = .650" valve lift).

I am going to change the cam lobe base-circle dimensions to avoid interference of the rotating cam lobes with each other. For example if a stock cam lobe base-circle is 1.305", decrease the base cam circle to 1.190", which allows an increase in valve lift up to .650" lift without interference problems (1.305" – 1.190" = .115" extra clearance).

1. If the stock cam valve lift is .473" (.473 cam valve lift ÷ 1.625 rocker arm ratio = .291" cam lobe lift), we can add this extra .115" clearance created by this clearancing method to allow a cam lobe lift of (.115" + .291" = .406").
2. The cam lobe lift for .650" valve lift cams is .400". There will be an extra .010" clearance above the .650" valve lift with a .406" cam lobe lift (.406 x 1.625 = .660" valve lift).
3. Therefore, .650" valve lift cams now fit in a chain drive by reducing the base circle measurement of a stock TC88 cam from 1.305" to 1.190".
4. In closing, to avoid colliding front and rear cam lobe interference:
5. Gear drives use the reverse-rear-cam lobe methodology.
6. Chain drives use cam base circle reduction techniques.

Using Stock Valve Springs

It is a good idea to use the stock Twin Cam valve springs when installing mild cams. If installing wilder cams requiring stiffer valve springs, a gear drive should definitely replace the TC88 cam chains. It is still a good idea but not as necessary to do the same with later TC96, TC103, and CVO 110 hydraulically adjusted timing chains. These gears will provide the reliable platform to increased performance.

Engine Power Productivity versus Emissions Reduction

I have briefly examined increasing engine efficiency by tightening up cam timing specifications to ensure that the spark plugs ignite the fuel mixture when the pistons are at their optimal positions. We accomplish this when replacing the timing chain apparatus in the Twin Cam with an aftermarket precise gear drive that prevents cam-timing wandering.

I have also demonstrated that different cam lobe profiles with higher lift and longer duration increase engine efficiency and can make the bike very much faster by allowing more air into the combustion chambers.

One thing I have not mentioned is emissions control parts, which are the:

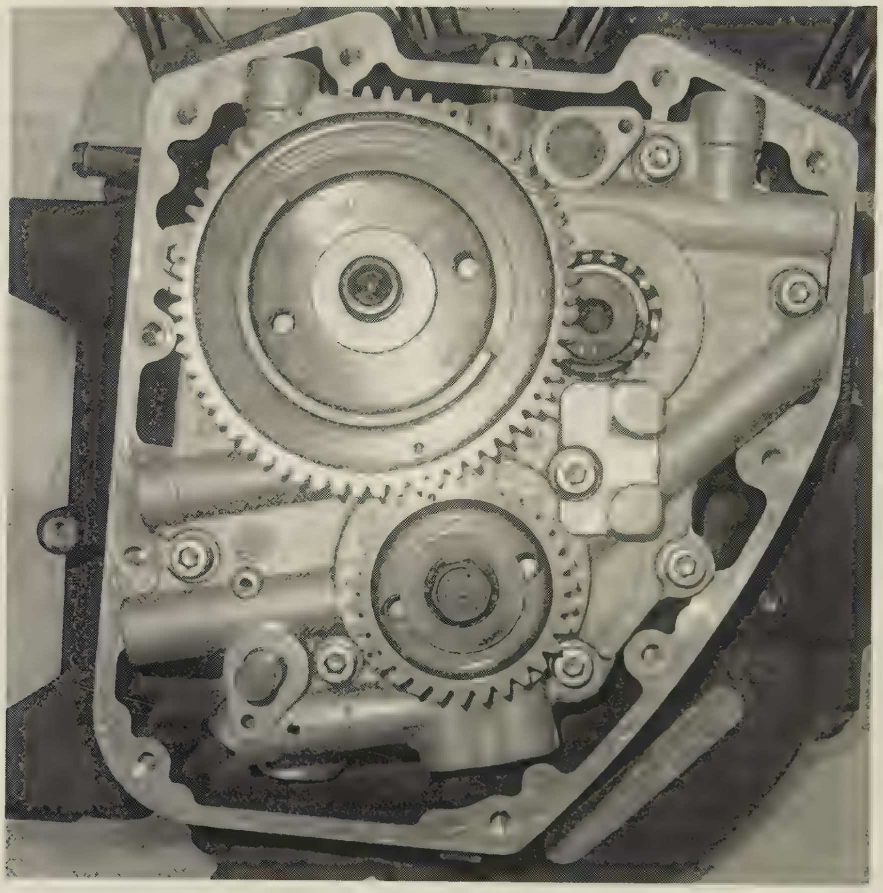
1. Exhaust.
2. Ignition.
3. Fuel delivery ratios.
4. Cam lobe profiles.
5. For example, the stock cams have restricted lobe profiles that in conjunction with other limiting emissions parts are designed to burn the most pollutants possible to reduce harmful emissions. Many times these stock lobe profiles suppress performance or power that is already there in the overriding interest of emissions reduction. This is in conjunction with the engine management system consisting of sensors, ECM, ignition, and fuel delivery that combine more and more fuel relative to the air.

Excess air creates heat, which burns a higher percentage of the fuel pollutants. I realize this may sound contradictory: more fuel burning but with less resultant power. A higher percentage of burn of a smaller amount of fuel is very efficient. However, there is still less fuel in the combustion chamber combining with a higher percentage of air. There is not more fuel available for burning, which would provide more power.

Engine Reliability with a Cam Gear Drive

There is a third reason that replacing the stock timing chain apparatus will benefit the Twin Cam over time and that is reliability. So, on the first Twin Cam engines let's look at the problems a gear drive will resolve.

1. As I discussed in the last chapter, there is a small ¾"-long bolt with a $^5/_{16}$" coarse-thread, along with a flat washer that holds down the 34-tooth cam drive sprocket. On early models, there is a chance that the head of the bolt may pop off because of too much stress. The bolt is a critical one. A keyway attachment holds this cam-drive sprocket to the end of the outboard journal of the rear cam. The keyway indent and a keyed protrusion from the inner diameter of the sprocket itself hold it in place. The problematic 1999 cam bolt I just mentioned clamps it down. This keyed protrusion may shear. Again, this will result in a critical condition. The gear drive will resolve these early issues



1999 to 2006 Gear Drive – Cam Support Plate, Outboard Side

Pictured is an S&S gear drive assembly installed in a TC88Twin Cam timing compartment. On a stock setup, two sprockets connect by a timing chain. The smaller gear attaches onto the end of the pinion shaft, which extends through the cam support plate. The gear hold-down bolt screws into the end of the pinion shaft. The larger gear bolts into the end of the rear cam journal sitting in its cam support plate bearing. The cams and their drive gears (not visible) are behind the support plate. A gear pressed onto the rear cam meshes with an identical gear on the front cam. Thus, the primary timing chain and sprockets on the outboard side of the support plate as well as the secondary timing chain with its two cam sprockets on the inboard side of the support plate are no longer used. Furthermore, the problematic spring-loaded timing chain tensioner adjusters also eliminate with the gear drive. The pinion shaft is part of the rotating right-side flywheel that drives the smaller *primary drive* gear that in turn drives the larger rear-cam drive gear, which powers the rear cam gear that powers the front cam gear, thus rotating the cams and their lobes to actuate the valve train. The four S&S gears are straight-cut spur gears and while superbly machined theoretically make more noise than the stock timing chain-sprocket drive mechanism. In practice, I have found some gear drives indeed noisier than the timing chains, some generating the same amount of noise and others quieter. Bob Wood is the inventive and knowledgeable man behind the Knight Prowler Advanced (Silent) Belt Drive System, which is a progressive step beyond the rest of the aftermarket in this area of timing chain replacement. Bob's really trick and beautiful kit is comprised of primary-belt-driven pulleys with secondary gears connecting the front and rear cams. His gear drive cams come with either spur gears or helical-cut gears. Helical gears are the quietest available since they are in contact all the time, thus eliminating backlash noise. I will examine the Knight Prowler in detail in Volume II: *Performancing the Twin Cam.*

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2. The rear cam ball bearing fiasco is a biggie. As I have already documented, a ball bearing, although quieter than a roller bearing, thus lowering engine noise cannot stand up to the stresses imposed on the rear chain-driven cam. A gear drive has different pressures applied to its cams. A ball bearing is very suitable for a gear-drive application and has worked efficiently without problems for many years. My two 1999 Road Glides were outfitted almost immediately with gear drives. Both are still on the road in 2010 and still running perfectly with their supposedly noisier gear drives and quieter support ball bearings.
3. As the years roll by, I can look at other evolving problems that are definitely resolved by a cam-gear-drive system. After the roller bearing fix for the rear cam outboard support journal, 1999 to 2006 premature wearing tensioner pads became the big issue. The sharp-edged silent cam chains wreak havoc with these pads. In addition, as they are spring-tensioned, the forces of the chains combating the springs or the hydraulic adjusters do not help one iota. A gear drive eliminates the need for these parts. Peace of mind ensues.

4. The gear drive corrects the problems of the bolt, washer, and keyway as well as the problematic rear cam ball bearing. Moreover, of course, the cam timing became precise.

By the end of the year 2000, Harley had also corrected the first four problems but the fifth, imprecise cam timing, remains to this day in 2011.

Apparently, the Factory never considered this important enough to rectify. The engine runs fine with this variance. It does not cause any perceptible problems. The rider will not experience seat-of-the pants awareness. Of course, there is no reference for comparison. However, this engine inefficiency issue needs to be addressed for a gear head and/or the performance-minded.

The Advantages of Gear Drives over Timing Chains

Gear drives, first developed by S&S Cycle, Inc. followed by Andrews, Crane, Wood, and others has the following advantages over the stock cam chain system on the Twin Cam 88 and 88B.

1. There is reduced maintenance since there are no chain guides or tensioner shoes to wear or replace.
2. Debris is eliminated from these wearing parts in the oil.
3. Cam timing is constant and accurate.
4. Cam chains can stretch while the gears remain stable.
5. There is a reduction of bearing loads since no spring-loaded cam tensioners are used.
6. Formerly necessary precision-machined spacers for timing chain sprockets are eliminated, therefore critical sprocket alignment is no longer an issue.
7. Use of higher cam lifts is possible with the gear drive since the gear cam lobes rotate differently than the cam-chain cam lobes allowing more space between rotating parts.
8. There is no worry about ball bearing failure.
9. Is the reader convinced yet? In fact, S&S supplies two quality ball bearings for the cam support plate instead of one for the front cam and a roller bearing for the rear cam for two reasons.

First, the gear drive alleviates the extra punitive pressures induced by the stock cam chains and their tensioners, which have an adverse effect on the rear cam journal ball bearing.

1. The rear cam roller bearing, which is necessary to combat the angled side forces generated by the primary cam chain will elevate gear noise. The quieter gear drive ball bearing solves this noise emissions issue. However, the cam gear drive gear interaction may generate more noise than a properly set up timing chain apparatus.

Therefore, there are three main reasons for considering the switch away from the timing chain-driven cams to gear-driven cams.

1. The first is for the efficiency-minded.
2. The second is for the performance-oriented.
3. The third is to correct potential mechanical breakdown from the stock components.

The Silent, Ongoing and Developing Issue of Pinion Shaft Runout

Briefly, I feel that the right side crank pinion shaft runout should not exceed .001". I will be constantly addressing this issue, particularly in Volume II: *Performancing the Twin Cam.* H-D seems to be relaxing flywheel and shaft allowable runout tolerances. I think that this is because all Twin Cam engines have isolated vibration from the rider by either rubber mounting the drive train or counterbalancing the engines internally. However, *an increase of internal vibration, whether felt or not by the rider, will decrease parts life, particularly all-important internal engine bearings.*

Furthermore, pinion shaft runout from .003" and greater will cause the cam support plate pinion bushing to progressively ream out, the greater the runout that occurs. This reaming action will cause a decrease in oil pressure to the bottom end crank pin, bearings and connecting rod races. This occurs whether using timing chains or a gear drive.

The timing chains can absorb this increase in tolerance since they are tensioned by a spring from 1999 to 2006 and hydraulically with the 2006 Dyna Glide and all 2007-to-present Twin Cams. However, their purpose is not to absorb and compensate for an out-of-true situation.

A gear drive does not have this luxury. The mating gears are unforgiving and rely on precise fitment. Exact fit cannot occur with an out-of-true pinion shaft since it is the driver of the gear system. Gear interaction will be too tight on the high side of the runout and too lax on the low side. S&S Cycle, Inc. in its *International Customer Support News Volume 1, Issue 2 Section, Tech Tip,* dated Sept. 17, 2008 advises "any pinion shaft run out greater than .003" will not be compatible with our gear drive kit and if installed could cause excessive damage." S&S gear drive installation instructions may be found on their website (www.sscycle.com) under instruction sheet number 51-1047.

This increase in allowable crank and/shaft runout is a burning issue that will unfold in a myriad of ways. I for one will be discussing this issue from many vantage points on an ongoing basis.

The Harley-Davidson Solution

Harley changed the type of chain and tensioner on the 2006 Dyna Glide and all 2007-to-present Big Twins. The new chain has a rounded edge, the tensioner pad is made from a different material, nylon and the tensioner is precisely and consistently hydraulically actuated and not susceptible to the vagaries of the spring-loaded tensioners.

The 1999 to 2006 rear cam journal INA SCE148 (H-D 9198) support bearings in Harley-Davidson's judgment are not a problem. I differ with the Factory perception as we have just taken too many Twin Cams apart for performance reasons, only to find what we consider adverse wear on these bearings. Furthermore, many of these engines had minimal mileage.

S&S and the now defunct Crane Cams supply replacement Torrington bearings with their cam-gear-drive kits to replace stock INA bearings. At Heavy Duty Cycles we replace the stock INA SCE148 (H-D 9198) bearings with Torrington B148's in *our entire* TC88 Twin Cam engine work.

The Factory made INA bearing changes in the 2006 Dyna and all 2007-to-present Big Twins. H-D stubbornly stayed loyal to the INA bearing but increased its size from the 1999 to 2006 specification of .875" a full .125" to a new and bigger 1.000" inner diameter. This, of course, meant that H-D had also increased the rear cam journals to 1.000" diameter from .875". This new, bigger, and stronger SCE 168 INA (H-D 9215) bearing is definitely stronger than what went before, perhaps a design admission by the Factory that they, too, must have seen adverse wear on the smaller INA bearings used in the TC88. We still replace these with the equivalent Torrington B168 bearings.

Harley made these dramatic changes on one tester model with the 2006 Dyna Glides. The 2006 Dynas have attempted to address 1999 to 2006 timing chain problems with a new system replacing the silent cam chains with a roller chain; a redesigned cam support plate; new hydraulic cam chain tensioners and the aforementioned increased load capacity INA inboard cam bearings in the engine casing. All the 2006 Softail and touring Big Twins retained the earlier 1999 to 2006 timing chest mechanism. The future is here as these modifications carried over into all the 2007 and later Big Twins. Some changes seem to be very much better and will eliminate some of the problems in the past.

The new roller chains do not have sharp edges like the 1999-2006 silent cam chains.

- Cam drive chain failure on these engines has not been an issue as of yet. Hydraulic units on the 2006 Dyna and all 2007-to-present Big Twins have replaced the troublesome and unpredictable 1999 to 2006 spring-loaded tensioners. They work much the same as a hydraulic lifter with a small spring inside to help tension while the hydraulic pumps up. An even and consistent amount of tension produces that is very similar to the hydraulic tensioners that have successfully monitored chain slack to the counterbalance chains in the Twin Cam B models since 1999.
- Nylon replaces the old shoe material.

By 2006, some engineers are finally acknowledging that the 1999 to 2006 tensioners can suffer excessive wear. Time is the only barometer of whether these changes to the 2006 Dynas will resolve previous wear issues. Some changes like the rounded timing chains and the hydraulic nylon adjusters look to be a real improvement. Often when a manufacturer like Harley-Davidson makes dramatic changes to fix one problem, new ones may evolve from the changes. One major concern I have with this new system is the elimination of cam support plate cam-journal bearings in favor of parent material bearings. Parent material bearings are just what the name says. The parent material of the cam support plate is the new bearing. Is the reader confused? Yes, I was, too, at first.

Moment Arm Force Creates a Potential Problem

A law of physics called Moment Arm Force, which describes leverage and resultant torsional stress, defines the main problem that surely will cause parent-material bearing holes to oval, particularly the rear one.

The inboard cam-drive-gears (sprockets) are positioned near the outside end on the front and rear cams. If the cam drive gears positioned in the center of the two cam lobes equidistant from both cam journal ends, no torsional force would occur, as it would evenly distribute along the camshafts.

The drive gear on both cams in all Twin Cam engines sits just inside the cam support plate, a fraction of an inch away. The cam lobes and their camshaft extend three or more inches back to their rear journal INA bearing supports. However, with the force applied by the primary and then secondary drive chains, Moment Arm torque will occur transferring its load onto the relatively soft parent-material bearing.

Why does the energy transfer the short way to the outside parent bearings and not back the long way along the camshaft into the INA rear journal bearings? The answer best explains anecdotally. There is a larger force applied to the parent bearing material. Visualize a shaft six feet long and have a person hold each end with the shaft in a horizontal position to the ground. Now, if I grab the middle of the shaft and apply 100lbs of pull towards me, their hands/shaft will move evenly towards me. Now, I will grab the shaft a few inches from the person to the right that represents the (cam support plate), parent material bearing. The other person to the left represents the INA bearing long end. Now I apply 100lbs. of pull to the shaft. The person to the right (parent-material bearing), will be affected far more than the person to the left (INA bearing), due to the distance.

The Moment Arm Force law of physical theory also applies to the 1999-2006 cam support plates with bearings.

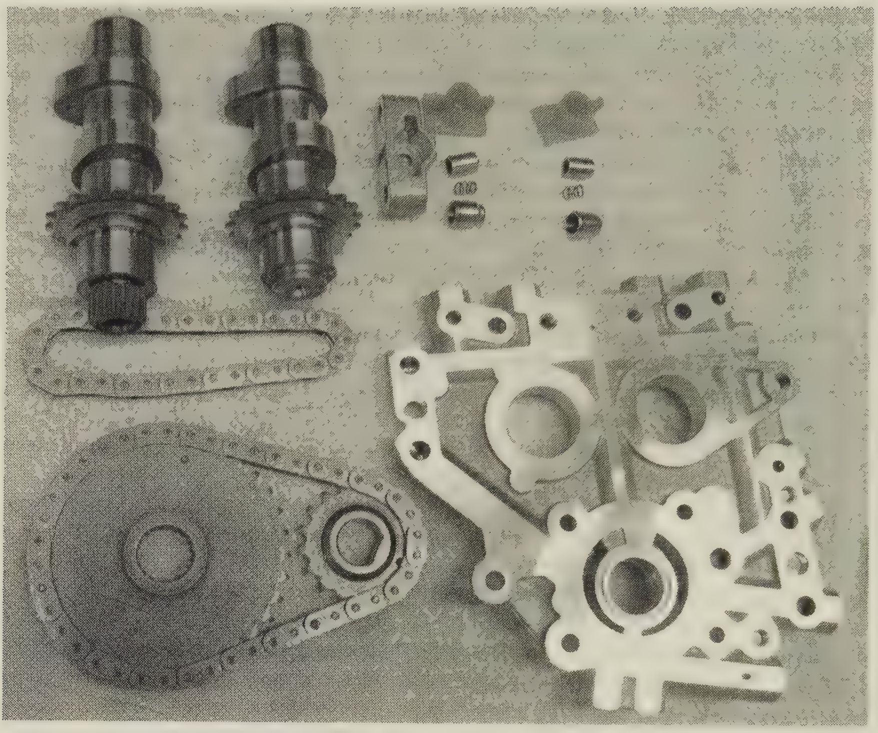
However, the correct bearings, roller in the rear and ball in the front, properly fitted withstand Moment Arm torsional forces because they are hardened steel with the same expansion rate as the cam journals.

1. Furthermore, the individual rear roller or front ball bearings can turn. They rotate in their cups to absorb applied Moment Arm torsion.
2. Thirdly, the entire inner bearing race and the complete set of rollers or balls can turn with the torque that needs to dissipate its twisting energy. This is dependent on the *outer race not being able to rotate* in its support plate hole.

Alloy parent-material bearings are softer than a hardened steel bearing, expand at a greater rate than the cam journals, and do not have roller or ball bearings to absorb the torsional forces, particularly on start-up.

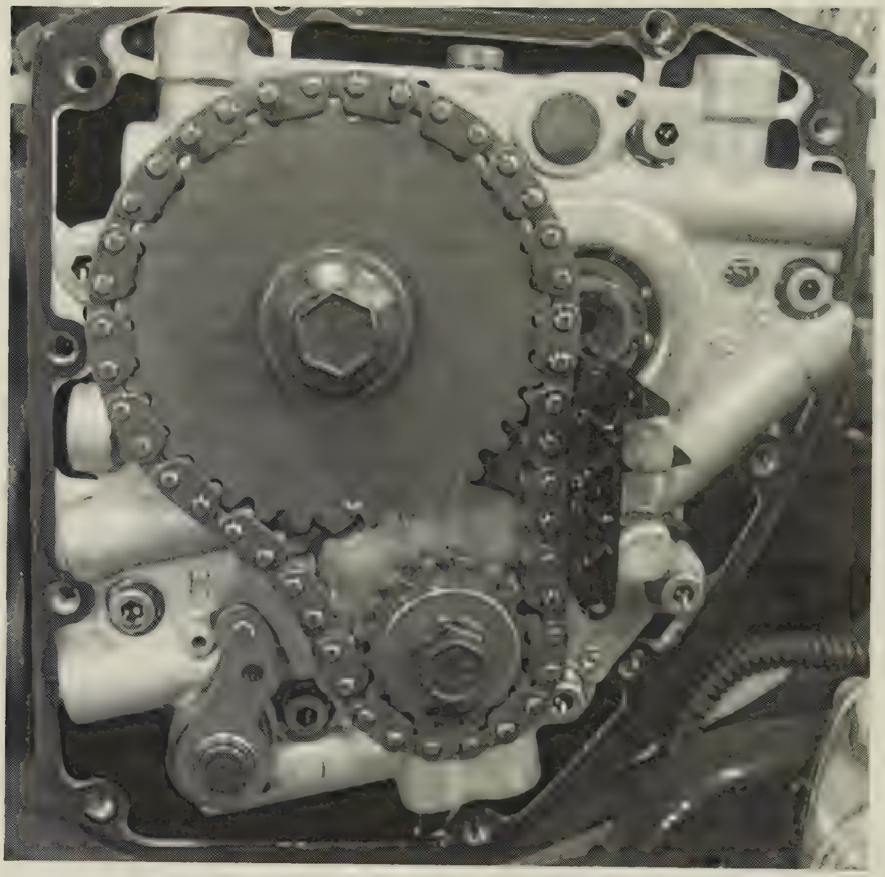
Once understood, start-up of a cold engine, lack of sufficient lubricant separating cam journal and parent-material bearing, with the sudden torsional force of the rotating cam journal in the parent-material bearing…well, won't the softer aluminum round hole begin to prematurely wear? The Moment Arm of torsional start-up force will wear a supporting bearing hole unevenly, eventually making it oval, which is obviously not a good thing. Time will tell.

The above comments relate primarily to the cam-support-plate camshaft parent material bearings. However, they are not applicable to the connecting-rod-big-end parent material bearings (races) or the 2011 elimination of connecting-rod-small-end piston (wrist) pin bushings in favor of parent material support. The reason is that the fulcrum is not off to one side creating Moment Arm Force as with the camshafts but in the center negating any offside energy transfer. Energy is equalized on either end of the crank pin and the wrist pins.



2007-to-present Twin Cam TC96 Timing Components

Pictured in clockwise rotation is a pair of 2007 TC96 cams (25590-07A rear, 24608-07A front). The cams are five-piece, allowing for the most appropriate metal and hardness for the separate cam lobes and the shaft with the increased size end journals. Not shown are the inboard INA cam journal bearings (H-D 9215), which increase in size from .875" to one full one inch (1.000"). To the right is a complete secondary chain hydraulic adjuster (39969-06) and a partial one without its body housing. The new adjuster pad is nylon. I hope this will resolve the many problems associated with the previous spring-tensioner adjusters. As of 2011 everything looks good. Below right is the cam support plate (25355-06), which has parent material bearings, top right and left to support the outboard cam journal ends. This makes me nervous. There are no bearings at all. The aluminum alloy-parent material of the support plate has replaced the actual front ball and rear roller bearings. Centered, below the parent material bearing holes in the cam support plate is the pinion shaft bushing (25344-99). In 2011, the Motor Company eliminates this bushing in favor of parent material. The bottom left pictures a primary chain (25675-06) and the new thinner sprockets (25673-06, 17-tooth pinion drive; 25728-06, 34-tooth rear cam drive). The new-style roller primary timing chain (25675-06) connecting the sprockets is radically different from the 1999 to 2006 *silent* chain. There are no abrupt edges to assist in tensioner pad disintegration. The slotted pinion sprocket mates with a similar slot on the end of the pinion shaft. The 2006 Dynas first used and tested the new changes. Above, center left is the shorter secondary chain (25683-06) that connects the two camshaft sprockets on the inboard side of the cam support plate. There are further pictures comparing early and late timing chains in Chapter XII: The 2007-to-present TC96 Engine. The 2006 TC88 Dyna cams as well as the TC96, later TC103 and the CVO 110 components look the same but may or may not have different cam profiles.



1999-2006 Outboard Cam-Support-Plate Primary-Timing-Chain and Cam Drive Gears

Pictured are the 1999 to 2006 cam drive sprockets on the outboard side of the cam support plate. Attached is the smaller 17-tooth pinion drive sprocket (25609-99) to the end of the pinion shaft, which provides rotating power. The primary *silent* cam chain (25610-99) attaches this sprocket to the larger rear 34-tooth cam-drive sprocket (25716-99). The rear cam-drive sprocket bolts to the outboard journal end of the rear cam. The bolt (H-D 898) holding this gear to the rear cam is the problematic one in 1999 to early-2000 that had a bad habit of *popping* off. There have been no problems with this bolt since then because of engineering redesigns. The 25533-99A cam drive sprocket retention kit includes two new bolts thrust washers for both primary sprockets have resolved the breakage issues. The rear cam journal (not visible), behind the rear cam sprocket rests inside a roller bearing (H-D 8983) that replaces the problematic 1999 to early-2000 ball bearing contained in the cam support plate. An inboard secondary silent chain (25607-99) rides on an integral cam sprocket just behind the journal and in front of the cam lobes in order to drive a similarly located integral sprocket on the front cam. The front cam end journal supported in its ball bearing (H-D 8990A) is just visible above the black plastic chain guide (39965-99) to the right of the rear cam-drive sprocket. Interestingly, we have never seen or had to replace a worn chain guide compared to the hundreds, if not thousands, of worn tensioner pads requiring replacement located on the opposite side of the chain mere inches away. The 2006 Dyna and all 2007-to-present Twin Cams replaced the silent chains with roller chains because it was felt that the sharp edges and chain link configuration contributed to premature chain tensioner pad wear. Shown on the lower left is the spring-loaded outboard primary chain adjuster (39954-99A). There is another adjuster on the inboard side of the support plate to tension the secondary cam chain. Hydraulic-operated nylon adjuster pads in the 2006 Dynas and all 2007-to-present Twin Cams mercifully replace the spring-loaded tensioners and pads.

The Spintron Dynamometer

An *American Iron Magazine* reader felt that I was wrong about cam-chain timing variances even though he liked the gear drive solution.

The Cam Timing Variance Challenge

He wrote: In the *AIM* 's December 2001 issue on page 28, "Donny Petersen has a total mechanical misconception of the Twin Cam's chain-driven cams if he thinks the chain tensioners have anything to do with valve spring tension. The tensioners are on the slack side of the chain. I agree with Donny's preference for the gear drive setup, but let's pooh-pooh the chain drive cams for the right reason…the damned weak rear cam bearing."

Before I replied to the reader, I discussed this with the likes of Tom Johnson, a much-respected techie at S&S at the time, along with S&S research and development people. They confirmed that, indeed, loading and unloading occurs even on the slack side of the cam chains. Okay, but how do we prove this? Well, S&S has high-speed videos that document that this loading and unloading in fact does occur. Now we are talking, but more on that and a remarkable tool that records this a little later.

I think we are getting a little ahead of ourselves here. I should restate the problem as I see it with performance valve springs. Sometimes, when installing high-performance cams and valve springs in the TC88, not all the performance expected was always forthcoming.

I suppose another way around this loading/unloading problem when utilizing performance valve springs would be to install stronger chain tensioner springs powerful enough to offset the increased valve spring tension. This is not a viable option. The tensioner shoes would wear even faster than they already do. They would dump more plastic into the engine oil and probably break a lot more often.

Notwithstanding heavier tensioners, the chain lash and cam timing would still fluctuate enough at high rpm to cost horsepower. As Scott Sjovall, who is in Research & Development at S&S says, "The guy has the right idea but does not have enough information to follow through with the thought. It is correct that the chain tensioners are on the slack side, but there is a horrific amount of harmonics in the V-twin valve train. There are several causes of these harmonics. One occurs when the tappets go over the nose of the cam and create a reversing load. Since we are dealing with only two tappets on each camshaft in the Twin Cam, this is a significant problem compared to multi-cylinder cams. They tend to have multiple lobes that offset each other. Other causes are pushrod and rocker arm flex and spring surge. All of these problems are aggravated when you elevate valve spring forces, especially in a Twin Cam engine. The different harmonics affect the chains and tensioners. The proof for all of these claims can be seen with our high-speed videos of the chain tensioner movements under different spring loads." [2]

Wow, this is amazing. A high-speed video of the engine interior while it is running!

S&S purchased a real nifty tool called a Spintron Dynamometer to analyze valve train dynamics in its Pro Stock engines. This is one of many reasons that S&S-sponsored bikes do so well at the track. The Spintron is also a fixture with many NASCAR and other race teams that use it for parts testing.

More importantly, this tool dynamically tests S&S parts that we as customers use on the street for reliability.

- It also proves whether the parts work as claimed.

The Spintron is an engine stand that uses compressed air to spin the engine to whatever desired rpm. Then, a high-speed video camera, sometimes used in conjunction with a strobe, records the action of whatever the user is interested in, be it valve springs, pushrods, cam chains, or whatever. Therefore, when S&S makes a claim for one of its parts, the claim is accurate since S&S has taken the assumptions, half-truths, and guessing, even though it is educated guessing, out of the equation.

Hundreds of variables sometimes affect a part's performance. Mechanical theory sometimes leaves the sphere of science and becomes an art for the experienced in trial-and-error experimentation. One misassumption or tiny error at the beginning of development may compound into, say, less longevity of a part or to a cam chain variance, which robs potential horsepower.

The Spintron is the only tool that allows a component developer or tester to evaluate independently the majority of the variables needed in order to maximize performance and durability. This cool tool will give live-on-time results on a screen and will document print analysis for later use. It will also do durability tests, component failure analysis, and document frictional horsepower loss for interacting parts such as the valve train.

Laser Video of Internal Engine Running

Laser Valve Tracking System

It just gets cooler as laser tracking of valve bounce, valve float, adverse valve spring harmonics, and deflecting pushrods document these characteristics to demonstrate that parts are working properly or need more development.

Step Testing

Furthermore, the Spintron Dynamometer allows tracking of these components from one specified rpm to the next and onto the next since a part may work fine at one speed or oscillation but not at another.

Although I digress, I have to relate another neat functional capability of this tool, which is regular interval rpm step testing of components like oil pumps. The Spintron can record vacuum, flow pressure, and horsepower required to run the oil pump at each predetermined rpm setting which allows for maximum efficiency development for the heart of your engine.

Cycle Testing

This is different from step testing which documents the effects of different rpm settings on a part, in that cycle testing simulates hundreds or thousands of race or street miles on your engine. It gets better. Components may assess as to their effect on each other; or they can test individually, say, one valve spring; or fifteen different valve springs tested at the same time against each other. It is cool! Performing this testing in extreme conditions is possible without fear of wearing out other engine parts such as con rods or bearings because they are not required to run the Spintron.

Thanks to the Spintron, which I have to confess I had never heard of before the advent of gear drives in late-1999, there is proof that the Twin Cam 88 cam chains do indeed load and unload, causing unwanted fluctuations in cam timing through both live video and print documentation. This directly affects horsepower gain achievements with performance cams.

Other technical writers have documented that mild cam changes do not add much, if any, horsepower in the TC88s. Now we have a very plausible explanation why. Moreover, this is an even better reason to convert to a gear drive in performance applications.

1999 to 2006 Cam Gear Drive Installation

There are expanded instructions for timing belt driven-gear drives in Volume II: *Performancing the Twin Cam,* Chapter II, *Repairing the Achilles Heel* that also includes installation of 2007-to-present cams.

General Installation Instructions

Use these instructions in conjunction with your H-D workshop manual and the instructions supplied with the gear drive cam kits.

1. Always disconnect the battery when performing engine or powertrain work. Do not wear metal rings. Inadvertently engaging the starting system and/or a shorting metal ring may cause painful injury and/or parts damage.
2. On Twin Cams, the covers are not load bearing like predecessor engines. Remove the timing cover following the instructions in the shop manual.
3. Using the Kent Moore cam chain tensioner unloader tool (H-D 42313) retract the primary cam chain tensioner. The retention pin part of the tool inserts into the support plate to hold the springs and tensioner pad away from the timing chain.
4. Repeat this procedure for the second tensioner after removal of the cam plate.
5. Remove the flange bolts and flat washers from the 17-tooth crank sprocket and the 34-tooth primary cam sprocket.
6. Use the crankshaft/camshaft sprocket-locking tool (H-D 42314). This locks the two sprockets so they can't turn during disassembly.
7. The 17-tooth crank sprocket drives the whole valve train as it attaches to the end of the rotating pinion shaft.
8. Gently ease off the primary timing cam sprocket and the crank sprocket. Remove these with the primary cam chain as a unit.
9. Mark the chain's outside plates to ensure they install back on the same directional way they came off.
10. Release the cam support plate from the oil pump flange by removing the four Allen head socket screws. Then release the cam support plate from the crankcase flange by removing the six Allen socket screws.
11. Now ease the support plate from the end of the crankshaft. It is not necessary to remove the oil pump from the pinion shaft
12. Examine the cam support plate to ensure a roller bearing supports the rear cam. A ball bearing supports the front cam.
13. The support plate part number should be 25267-99B. If your bike has an earlier support plate with a different part number and two ball bearings, it will be prudent to upgrade to the latest cam support plate. I did this with both my 1999 Roadglides.

Remove the bearing retaining plate from the back of the cam support plate.

1. Use the Kent Moore camshaft remover/installer tool (H-D 43644) to press both camshafts and bearings from the support plate at the same time.
2. After removal of the stock cams from the cam support plate discard the chain tensioners as they will not be required with the gear drive.

Always use new cam journal bearings in the support plate.

1. Also, replace the engine case cam bearings, substituting Torrington bearings for the stock INA bearings.

Do not reuse bearings. New bearings are supplied with the S&S Camshaft Installation Support Kit (33-5163).

Apply assembly lube to the outer races of the cam bearings and the bearing boreholes in the support plate.

1. Install new bearings using a hydraulic press and Kent Moore camshaft/remover tool (H-D 43644).

2. Many times the bearings will fit into their respective support plate holes with a hand press. If so, replace the cam support plate to ensure a press fit. This loose fitment will allow the ball bearings to spin in the bored cam support plate holes, which will eventually enlarge them via the physics principle of Moment Arm Force, leading to a completely new host of problems.

I have seen cam support plates with egg-shaped support holes. The pull-and –push stresses on the cams will cause particularly the rear borehole to wear this way, as opposed to increasing the diameter proportionately.

- Ball bearings must be used front and rear with the gear drive because a roller bearing is inappropriate for the new stresses and will make too much noise.

1. Lube the outer bearing journal surfaces of the cams and the inner races of the
2. bearings. Press the front shorter cam into its bearing first.

Use a new retaining ring.

1. Then do the same with the longer, rear cam ensuring alignment of the timing marks.
2. To avoid damaging the ball bearings' inner cups during installation, the bearings require support by the inner races.

Camshafts over .600" lift (stock is between .471" and .490"), such as the S&S 625G (.625" valve lift) or the 640G (640" valve lift), require the crankcase be relieved a minimally to provide .030" clearance for the cam lobe rotation.

- Always check for cam lobe clearances by rotating cams when installed in the crankcase needle bearings.

- Remove the INA camshaft needle bearings from the crankcase using

1. bearing/remover tool HD-42325. Replace with Torrington bearings B-148 (1999 to 2006) or B168 (2006 Dyna and all models 2007-to-present).

Always replace O-rings. Some O-rings are close in sizing to others. Pay particular attention that correct sized O-rings are used.

a) Apply assembly lube to all surfaces that move against and with another surface.
b) Align camshafts with the needle bearings and gently slide the support plate over their alignment dowels. Do not force!
c) Use blue Loctite and torque to the lower end of Harley recommended specifications. Torque bolts alternately in correct sequence as demonstrated in S&S instruction sheets.
d) Install oil pump bolts; torque to 95 in-lbs, alternately sequenced.

1. Using red Loctite on the threads and a drop of 20W50 oil under the Grade 8 bolt flanges, install the crankshaft gear, timing mark out, on the crankshaft first. Torque this bolt to 25 ft-lbs.
    a) Put drive gear key in rear camshaft (1999 to early-2000).
    b) Place cam drive gear on rear camshaft. Rotate until timing marks align.
    c) Use the thick washer supplied and torque to 34 ft-lbs.
2. Check the cam drive gear for interference with the cam cover. Ensure there is .030"
3. play between the two by measuring with clearance putty (Plastocine) and relieving the cover as necessary.

The area of concern is between the two top right-hand cam support cover bolts. Place the putty inside the cover.

a) Gently install and remove the cover.
b) Measure the compressed putty.
c) Relieve cover if necessary. Double-check with putty clearance.

   d) Install the timing cover.
   e) Discard stock fixed-length pushrods and install adjustable pushrods.
4. The longer adjustable rods are for exhaust valves, the shorter ones for the intakes.
   a) Rotate engine until front lifters are at their lowest point.
   b) Turn adjuster screw on front exhaust pushrod until there is no up-and-down play but will still allow rotation of pushrod with light finger pressure.
   c) Turn screw a further twenty flats which equals 3 ⅓ revolutions.
   d) Repeat procedure for front intake pushrod.
5. Allow the hydraulic lifters to bleed down for 10-15 minutes, before proceeding.
   a) Do not rotate engine until lifters bleed down or something expensive will bend and/or break.
   b) Rotate engine and repeat the above steps for the rear cylinder pushrods.
6. The engine will be noisy on start-up for a few miles as the hydraulic lifters fill with oil before quieting.
7. At Heavy Duty Cycles, we always install the S&S limiter lifter rings into the hydraulics to ensure hydraulic lifter quietness with solid lifter performance.

It is extremely important to use the proper tools, removal and installation procedures, torque specifications, and torquing sequences. If your mechanic does not have all the TC88 tools, he cannot do the work competently. I cannot overemphasize this. Twin Cam engine work is not for the novice. The shop manual is *mandatory* reading.

With that out of the way, is the S&S gear installation easy? Sure it is. In fact, it is much easier than installing the stock components.

Is it quiet? Well the cam locations and gear lash is dictated by the cam support plate. S&S warned me that it would not be as quiet as the stock timing chain setup because Harley used loose tolerances with the support plate. The 1999 Road King that we did the installation on ran quieter with the S&S gears than it did with the timing chains.

Well, I have never been impressed with the TC88 for quietness. The prototypes that I viewed in Milwaukee were quiet, but my own Roadglide, for example, is as noisy as a properly installed Evolution timing gears.

The S&S gear set we installed (585G), for this project was not offensive in the noise department at all. It was just as quiet as my stock Roadglide.

Now we can use the proper valve springs for these cams, up the compression, do fancy headwork, go big bore, stroke the engine. In fact, we are now free to do whatever high-performance modifications we like without being restricted by the limits of the timing chains and their tensioners.

Gear Drive Specifications

The following kits were the first introduced by S&S and the aftermarket. I list them for comparison and interest. A more comprehensive list of other manufacturer gear drive cams, specifications, and recommended usage will be in Volume II: *Performancing the Twin Cam.* The Internet is a great tool for the latest and greatest. Listed below are the S&S kits for 1999 to 2006 in the accompanying chart.

The 510G-cam set is for 88-95 cubic inches with compression ratios up to 9.5:1. This is for those that want mild high-performance with no timing chains.

- The 570G-cam set is best for 88-95 cubic inches with compression up to 10:1.
- The 585G-cam set is for the same cubes but with compression between 10.0 and 10.5: 1.

- The 625G cams are for 95 cubes or more with compression between 10.0 and 10.75:1.
- The 640G cams are for 95 cubes or more with compression ratios between 10.5 and 11.5:1.

New kits were introduced at later dates for 1999 to 2006, such as the 546G with .546" lift and the .675G with an astounding .675" lift.

The kits listed in the following table along with a variety of others are also available for 2006 Dyna and all 2007-to-present Twin Cams.

KIT	CAM	LIFT	DURATION	OPEN/CLOSE
510G #33-5177	IN.	.510	238°	20° / 38°
	EX.		252°	52° / 20°
570G #33-5178	IN.	.570"	240°	20° / 40°
	EX.		255°	55° / 20°
585G #33-5179	IN.	.585"	245°	20° / 45°
	EX.		260°	60° / 20°
625G #33-5180	IN.	.625"	255°	20° / 55°
	EX.		260°	60° / 20°
640G #33-5181	IN.	.640"	265°	25° / 60°
	EX.		265°	60° / 25°
Stock H-D TC88 Carb.	IN.	.473"	216°	-02° / 38°
	EX.		220°	36° / 04°
Stock H-D TC88 EFI	IN.	.473"	216°	02° / 34°
	EX.		220°	36° / 04°
Stock H-D TC96 EFI	IN.	.471"	196°	09° / 25°
	EX.	.474"	220°	39° / 01°

[1] Andrews, John. 2007. *Andrews Cams and Gears for American V-twins.* Andrews Products Inc. catalogue. Page 20.

[2] S&S Cycle, Inc. Research and Development. Technical Support, Scott Sjovall; discussion 2002.

CHAPTER IV

Harley Oil Leaks: Marking its Spot

Marking its spot has been a time-honored Harley tradition until the advent of emissions controls dictated by EPA. Harley's left evidence of wherever they traversed by telltale oil drippings on the ground ever since 1903. Even today's Twin Cam, the tightest of all Harley oiling systems, occasionally leaves its mark.

The best venting-breather system designed by the Factory to date is found on the Twin Cam, but alas, too often it proves inadequate when riding at sustained high rpm and/or when increasing engine displacement from the stock 88c.i up to the very popular 95 inches or 96c.i up to 103 cubes. I will not even get into what can happen when increasing displacement to 116c.i or 124c.i with superlative aftermarket kits manufactured by the likes of the venerable S&S Cycles (www.sscycle.com), or the relatively new, but no slouch, that is for sure, JIMS Machining, (www.jimsusa.com). If building one of these behemoths without extra venting modifications, ride one of these big-inch babies at sustained high rpm and see what can happen with blowby oil emanating from the breather. Of course, JIMS, S&S or other manufacturers like TP Engineering (www.tpeng.com) have proprietary built-in venting assists with their crate engines.

The 2007 TC96 has an improved oil pump that the Factory hopes will alleviate excess venting to the outside world by increasing the return side of the pump by 23%.

Oil Blowby Aftermarket Fixes

If you happen to have a stock Twin Cam or Factory 95c.i or 103-incher or any other size Twin Cam that spews oil out of the breather, the solutions involve simple aftermarket fixes.

The engine builder will need to incorporate the S&S invention of a reed valve that fits in behind the oil pump on Twin Cam A models; a Doherty breather apparatus, or the TP rocker boxes to control oil blowby out the head breathers.

- Tom Pirone of TP Engineering has a great fix with his ProVent dual-chamber breather rocker boxes designed for the Twin Cam A and B engines as well as earlier Harley 1992 to 1999 Evo Big Twins and 1991 to 2003 Sportsters.
- Tim Doherty of Doherty Machine (www.dohertymachine.com) has crank vents and the Mystfree breather apparatus as well as top-end breather vents for late Evos, Sportsters, and, of course, both model Twin Cams.
- I will also discuss in detail a new S&S reed valve for Evolution engines in Volume IV: *Performancing the Evolution* that is also a godsend to control oil carryover.

The EPA Dictates the Control of Oil Blowby

Controlling blowby, also known as oil carryover or oil venting, has been an always-present and nagging problem for Harley-Davidson. The ever-tightening Environmental Protection Agency policies began with amateurish vigor in the seventies. Initially regarded as an irritant, half-hearted efforts on the part of manufacturers resulted in stricter controls. It is difficult to pinpoint the first changes made for no other reason than controlling emissions but 1978 is a good year to begin looking. Sometimes the attempt at positive change resulted in negativity all the way around.

The Shovelhead Blues

Witness the white-and-blue smoking oil problem that occurred on the Shovelhead circa 1978. With the advent of the 80c.i engine over its predecessor the 74c.i engine, Harley-Davidson made some changes for what reason I could never figure out.

Shorter and Fatter Valve Guides

The Factory began using shorter valve guides ((18109-81/18108-81), that left less mating surface to control oil getting past the guide and valve interface. The shorter valve guides could not prevent oil from getting by and into the combustion chamber. Once there, oil burns in the combustion process, sending a steady hazy blue-and-white smoke out the exhaust pipes. In addition, Harley-Davidson made the valve guides outer diameter fatter preventing retrofitting earlier longer valve guides as a solution.

Initially, I feel the engineers' incorrectly concluded that this was a venting problem.

I think they felt that ascending and descending pistons displacing air throughout the engine cavities was the cause forcing the oil past the guides. H-D has always had venting problems right from 1903 to present day, but this was not one of them.

The engineers probably felt that running an external vent line from each guide block to each cylinder base would cure this blowby situation. The Factory inserted fittings (18599-81) into the guide blocks to allow the transfer of air between them and into the cylinder bases via other inserted fittings (62375-57). A rubber hose (63501-68) connected the fittings for the front guide block to front cylinder and the rear guide block to the rear cylinder. This procedure allows the venting of gases displacing up the pushrod tunnels into the heads and thus by the valve guides an option to also vent back into the flywheel compartment. That's nice but not the cure for this particular venting situation.

Theoretically, without much thought, one might assume that this might even work. However, how could it? The pistons are descending on the intake and power strokes and thus displacing the air underneath. There is no room for this displacing air to vent back into the engine compartment because there is no room until the pistons start to ascend again. There is no need to vent air that is no longer displacing since the pistons are going upwards on the compression or exhaust strokes.

The one positive with this apparatus is that oil in the pushrod tunnels might drain over into the cylinder base providing some more lubrication for the pistons. The Factory removed this vent after about two years.

The guide blocks house the hydraulic roller tappets that follow the dictates of the camshaft lobes as part of the valve train. Guide blocks used up until the demise of the Evolution between 1998 and 2000 discontinued with the advent of the Twin Cam when the engine casing itself performs this function.

Harley-Davidson's First Use of Valve Guide Seals

In order to cure the smoking problem, H-D began use valve guide seals (18000-81) for the first time on midyear 1981 Shovels and uses them to this day improving their quality as the years passed by.

The Aftermarket Cure

It seems that it never occurred to the engineers to return the 80-cubic inch valve guides to the longer length used successfully for so many years on the 74-cubic inch Harley-Davidson's. We in the aftermarket figured the Shovelhead valve guide dilemma out pretty quickly. Longer valve guides manufactured by the aftermarket substituted for the shortened H-D counterparts. However, Harley did lengthen the valve guides (18130-83) again in 1984 with the introduction of the Evolution engine with much success. To be safe, the Factory also kept using valve seals with the longer supportive guides. These changes continue with the Twin Cam models.

Twin Cam Valve Guides

The Twin Cam uses the same guides as those in the Evolution up until around 2004. H-D then began use of thinner stem valves (intake 18074-05, exhaust 18085-05) to lower valve train weight. This necessitated smaller bore holes in the valve guides (16461-02). The Factory kept the length of the valve guides the same.

The Twin Cam also adopted a single beehive-shaped valve spring (18245-02) to replace the dual valve springs, one inside the other that has been in use since 1984. The lower valve collar (18094-02) also began to incorporate an improved valve seal.

Life inside an Engine

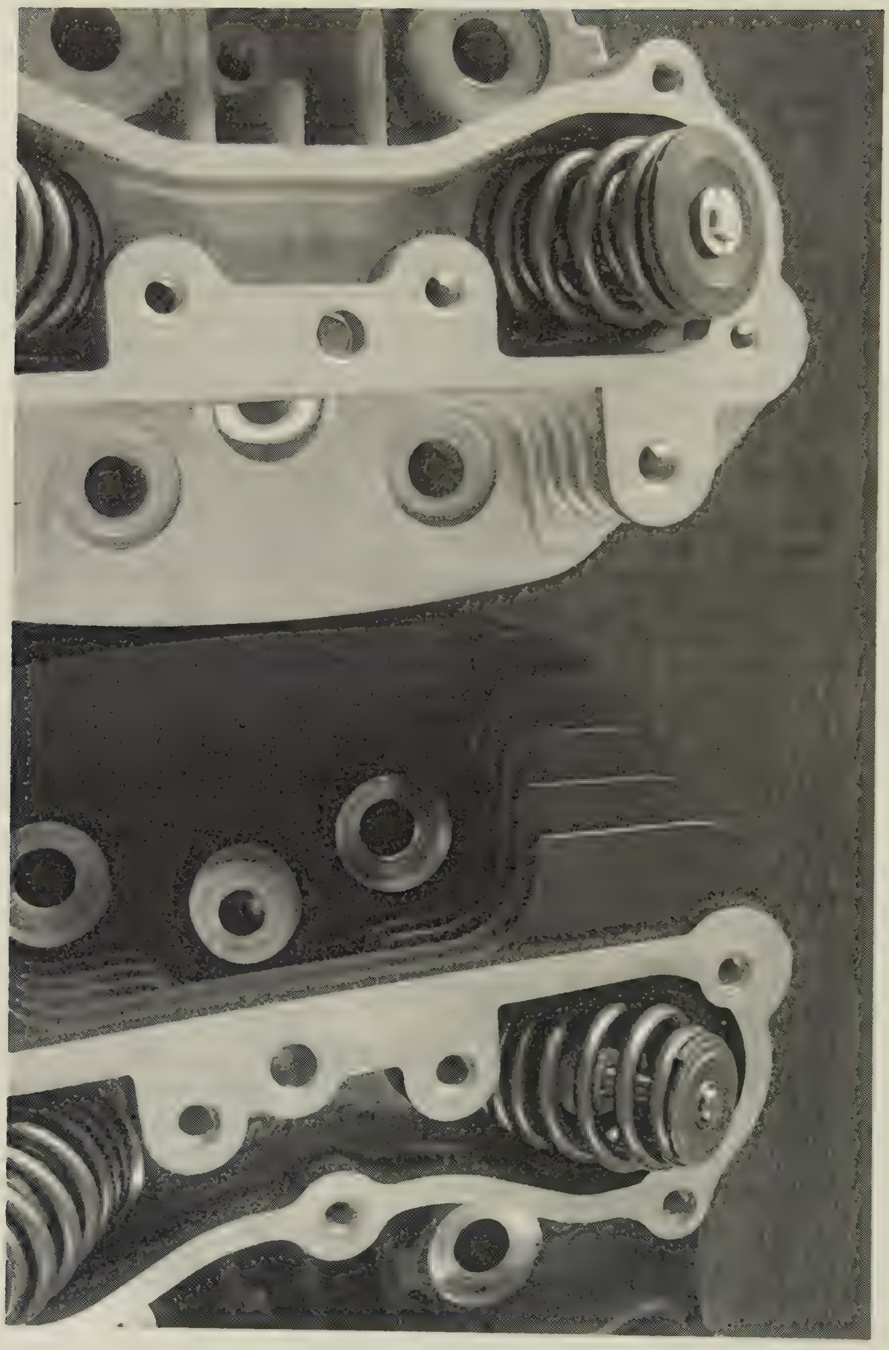
It is a violent but controlled world inside a Harley engine with churning, rotating, and reciprocating parts. Air constantly displaces forcefully throughout the engine. This air pushes powerfully about by moving parts making spaces smaller. Parts movement also makes some areas bigger; creating a negative pressure (vacuum) that pulls and sucks air back into these voids.

Centrifugal Lubrication

Churning, rotating flywheels pick up oil in the bottom of the engine compartment and fling it in every direction via centrifugal force. The purpose of this is to lubricate parts like the cylinder walls through fling lubrication.

Oil Jet Lubrication

Piston oil jets squirt oil to the undersides of the pistons in the Twin Cam engines to remove heat from the piston crowns, but also for a different method of oiling. Oil dripping back down via gravity will run into oil holes like the wrist pin hole to lubricate the piston wrist pins and the wrist pin bushings in the small ends of the connecting rods.



Twin Cam Valve Spring Comparisons –
Early and Late Configurations

Pictured are early and late TC88 heads. Early 1999 to 2003 Twin Cam heads (top) use the same valve springs and inner diameter valve guides (⅜” + .001” to .003”). These parts had first use in 1984 with the advent of the Evolution engine. The intake valve (18074-83A) continues use from the Evolution while the exhaust valve (18085-99) looks identical to its Evolution counterpart except the valve head is .060” smaller. The early valve springs are dual with one spring inside the other (18201-83 outer, 18202-83 inner). A valve seal (18001-83B) presses onto the top of each valve guide. Circa 2004, H-D began using 5/16”- thinner stem valves (18074-05 intake, 18085-05 exhaust) to lower valve train weight, which necessitates smaller guide holes in the valve guides (16461-02). Valve heads become tulip-shaped for superior flow characteristics. Valve guide length stays the same. Pictured on the bottom, the Twin Cam also adopts a single beehive-shaped valve spring (18245-02), to replace the dual-valve springs, one inside the other, in use since 1984. Beehive valve collars (18258-02 top, 18094-02 bottom) and valve keepers (18260-02 x 8) also change. The beehive shape prevents spring fibrillation at high rpm because the spring coil diameter tightens with differing physical characteristics producing progressively changing coil strengths. The lower valve collar also incorporates an improved valve seal. In 2007, the TC96 heads use the same late style TC88 valves and guides but head port shape of the intake and exhaust tracts improves for better air flow.

Drip Lubrication

This drip lubrication methodology is also used elsewhere. Supported in the left engine casing by sprocket shaft bearings is the left-side (power-side), flywheel sprocket shaft that transfers engine torque to the powertrain. A simple hole above these enclosed bearings allows flung oil onto the side of the engine casing to enter the oil hole and drip down into the bearings.

Controlled Mayhem

The point is that oil pushes, pulls, flings, and squirts all over the place in controlled mayhem. Some of it will vaporize and form an oilified gas. Combine this with mass transfers of air thousands of times per minute (rpm), and oil vapor creates.

The ascending pistons create a negative pressure in the bottom-end compartment and suck air first from the timing chest and then the top end via the timing chest through the pinion bearing and into the bottom end. A millisecond later the pistons descend, violently pushing this gaseous air back through the pinion bearing into the timing compartment and up the pushrod tunnels into the top-end compartment. Back and forth, it goes at very high speed, thousands of times a minute. Whew!

Early Air Venting

The engine must vent allowing some air to escape as it displaces. Air like a liquid will always equalize if given free movement. I discussed other types of venting at length in Chapter II: *1999 to 2000 Teething Problems.*

Early Shovels and their predecessors directed these venting gases out of the engine case to open air. The vent was just a fitting in the rear of the right-engine casing. It usually had a hose attached that vented the gaseous mixture downwards. Hence, the term *marking its spot* evolved! This vent fitting with a hose attached also doubled as a rear chain oiler, which effectively speaks to the lack of an oil-air separation process on these earlier engines.

The Thinking Mechanics Partial Cure for Oil Venting

Thinking mechanics came up with a fix for normal oil venting out of the vent along with air. The fix is partial, depends on gravity, and the fact that oil is heavier than air. The mechanic will extend the vent line away from the ground and upward anywhere from 6" to 16". Air can still easily escape, but the oil in the air must now defy gravity as it tries to work its way up the elevated vent line.

If the vent line oil discharge is not too severe, gravity will separate the oil, which will run harmlessly back into the engine for return to its oil tank. The aftermarket developed a little vent filter apparatus that fitted on the end of the vent line. This also helped especially if combined with a rerouted, elongated, and elevated vent tube.

Burning Vented Engine Vapor

In later years, this line connected to the back of the air breather. The procedure helped further separate the heavier oil that in theory was not supposed to be there in the first place from the air via gravity. The misty oil-laden air flows into the breather, sucks into the carburetor venturi, and burns with the fresh intake charge of fuel and air. From an engine-efficiency or performance perspective, this is not ideal, but the pollution cops were on the case.

Each successive new modification by the Factory worked better than what went before but invariably did not work well enough. Each satisfied the EPA to the point that at least there was improvement but never enough. The EPA master plan was and still is to progressively decrease pollutants or come as close as possible to eliminate contamination of the environment altogether. The pollutants are venting oil and fuel, oil leaks, exhaust emissions, and noise.

Honda Motor Company announced a few years ago that it had developed an internal combustion four-stroke engine that was 100% pollution free. It sounds impossible. I have not heard much about it since, but this is the direction vehicle design is going in.

With each improvement, though, Harley's still inevitably marked their spot.

Let's look at how 1984 to 1991 Big Twins vented, which is essentially the same as late Shovels, and compare it to the 1992 to 1999 Evolution models. Oil feeds into the rocker boxes, returns to the crankcase through a drain hole via gravity in the head and connecting to the barrel or cylinder.

The Rotary Breather Valve 1936 to 2000

The rotary breather valve had use on Knuckleheads (1936 to 1947), Panheads (1948 to 1965), Shovels (1966 to 1985) and Evos (1984 to 2000) but not the Twin Cam (1999-to-present).

The breather times to open on the down stroke of the pistons. This allows the displaced air pressure from the crankcase to expel the collected oil at the bottom of the crank casings, through the breather valve into the right side timing chest, more correctly called the cam gear compartment, in Harleyese.

The oil and air mixture that pushes up into the rockers is supposed to separate in the breather apparatus from 1992-to-present. The separated air vents out of the heads and the oil flows back into the bottom end via the oil drain hole in each head and cylinder, once again via gravity.

The heavier oil falls to the bottom of the timing case, where it enters an oil hole that takes it to the two scavenge return gears in the oil pump. It then feeds through the oil filter and on to the oil tank reservoir.

There will be much more on the rotary breather valve in a subsequent section in this chapter. This is not to be confused with the Twin Cam system that utilizes an internal oil pump that sits around and is driven by the rotating pinion shaft. The Twin Cam pump no longer uses gears but geroters that squeeze the oil to create pressure.

The oil filter on the Twin Cam is on the feed line from the oil tank reservoir to the engine. The filtration is not on the return line to the oil tank as in all predecessor models.

Baffling Separates Oil and Air

Back to the early 1984 to 1991 Evolution, where separated air is still impregnated with a light oil mist that requires further separation. The air routes around a baffle for additional separation and through a passage in the timing gear cover. Two more baffles, one in the cam cover and the other in the crankcase further separates oil from air.

Baffles take different shape and form but are essentially a mechanical device that is an impediment for a liquid or gas to maintain the same composition. For example, directing an oilified mist directly at a plate so that the gaseous mixture must change direction suddenly will cause heavier oil molecules to liquefy and drop down to the lowest point via gravity while a lighter air can rise, go sideways, or down.

Tortuous Pathway Oil Separation

Twin Cams use a tortuous path for the mist to travel before exiting the heads into the breather. This convoluted pathway encourages the oil to separate and drain away.

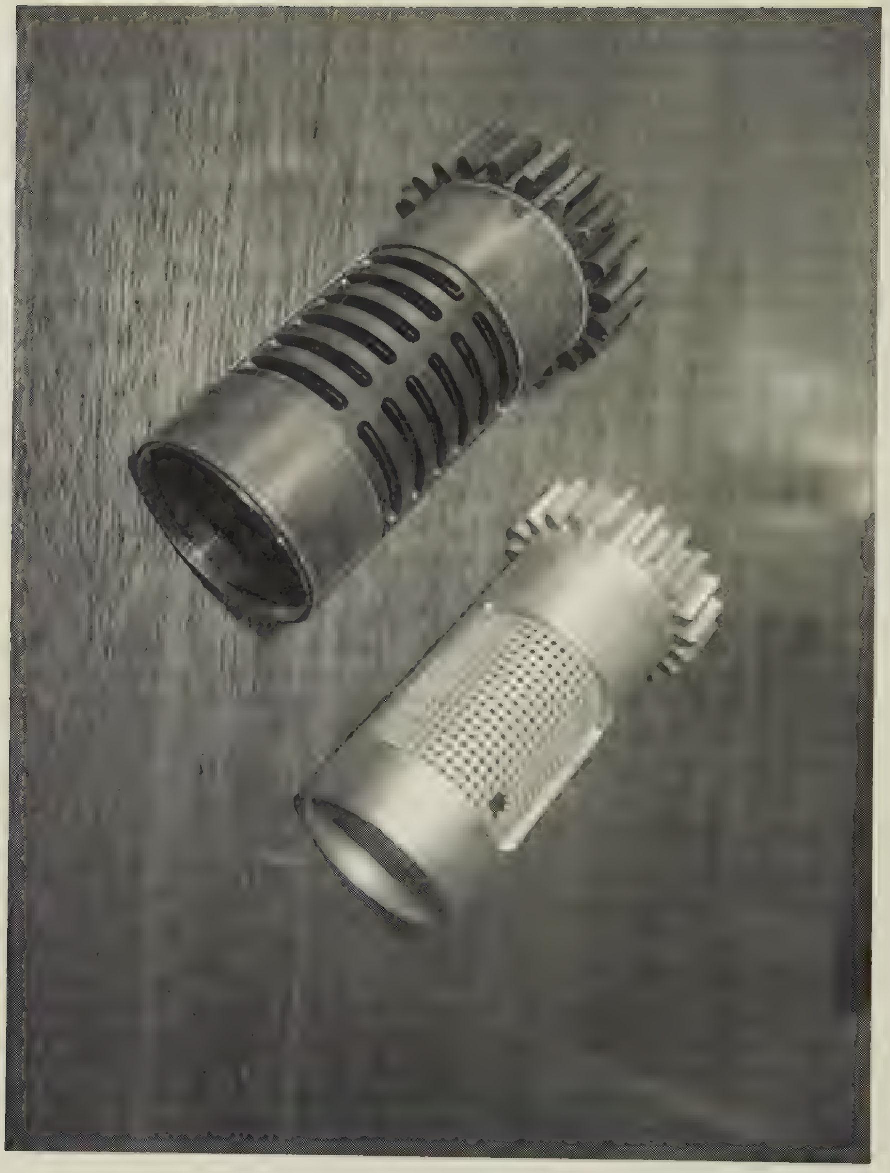
Vacuum Separation

In an Evolution, the oil drops to the bottom of the baffling compartment. As the pistons go up their respective cylinders, a vacuum is created that draws this oil back though a timed opening in the breather valve.

The separated air continues through the crankcase passage out to an external oil line up to the carburetor air breather. In an ideal world, the air mist will draw into the carburetor venturi and burn, thereby eliminating some pollutants. However, as any Evo rider knows from practical experience, sometimes too much oil makes its way up into the breather and drips or splashes down the side of the bike.

Venting the Crankcase to the Oil Tank

A separate line to the oil tank also vents the crankcase and timing chest, which at the same time also allows air to displace draining oil from the oil reservoir.



Evolution Engine Plastic Breather Valve Comparison
with 1940's to Early-1977 Steel Breather Valve

Pictured on the bottom is an old-style steel rotary breather valve used in various configurations from circa 1948 to early 1977 (OEM 25313-73) and the new-style plastic breather valve on the top in use with differing number aperture rectangular-slot-openings from late 1977 to 2000 (25313-77, 25310-82A, 25310-82B). The advent of the Twin Cam discontinues the use of rotary breather valves that sumps oil from the bottom end compartment into the timing chest area for scavenging back to the oil reservoir. Many engine builders never became fans of the plastic valve, as they prefer the steel one although the plastic version works very well. The aftermarket continues to manufacture steel breather valves to the present day for all years. Some criticize the slots used in the plastic valve as opposed to a mesh screen utilized in the steel one because they will allow larger abrasive particles entry into the gear cavity where they may damage gears or the oil pump. The Twin Cam does not require a breather valve for two reasons. First, top end returning oil redirects into the timing compartment, no longer emptying into the bottom end compartment. Secondly, the Twin Cam has a sump (opening) at the bottom of the bottom-end-compartment engine cases that channels any bottom end oil via gravity over to one of two suction ports on the Twin Cam oil pump for scavenging back to the oil reservoir.

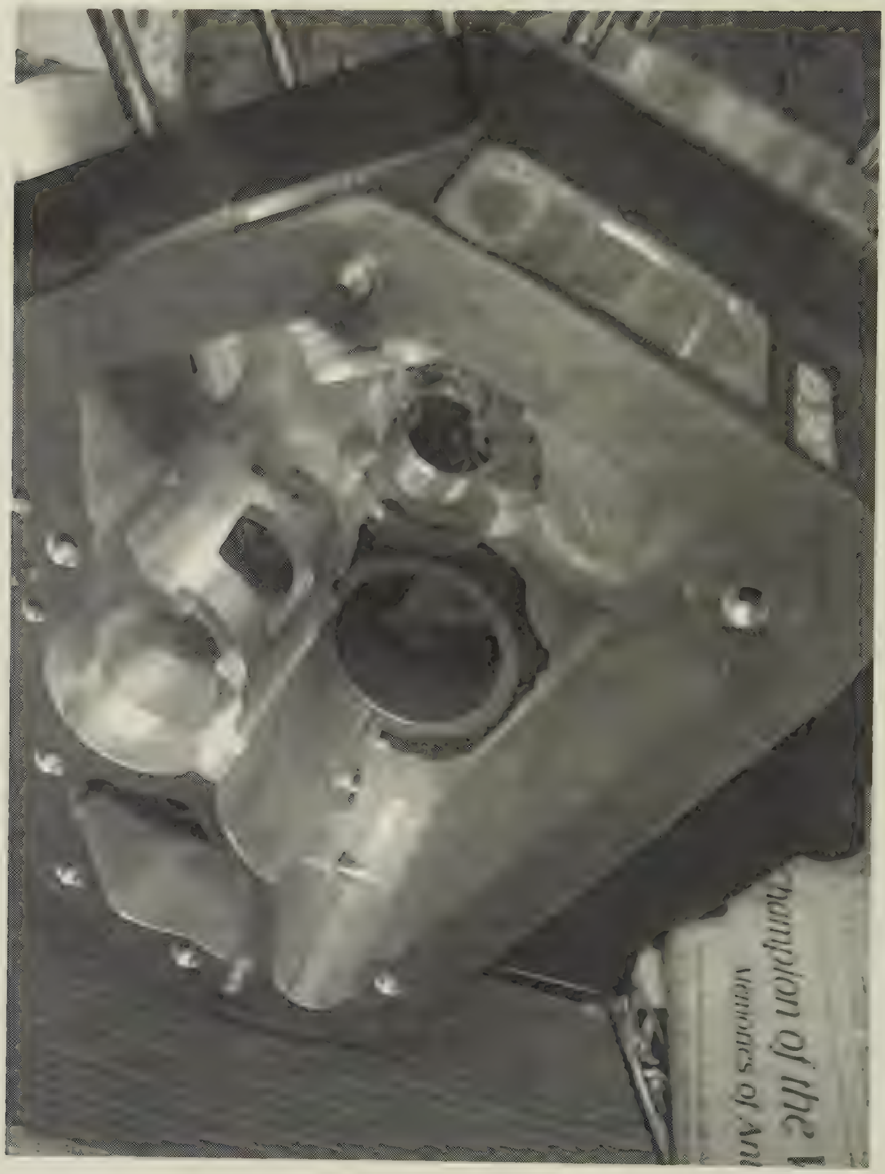
Oil Drainage Interference

If reading H-D workshop manuals, they will say that the positive timing chest air pressure caused by descending pistons pushes air up the pushrod tunnels into the rocker boxes. What is misleading is that they also say that this pressure helps evacuate oil from the rocker area into the head-cylinder drain holes. This is very logical and very easy to accept mentally without further thought.

However, it is not the whole story. S&S Cycle, Inc. in the development of its reed valves that for the most part eliminate oil carryover/venting/blowby discovered that the descending pistons also create a negative pressure up the cylinder drain holes that interferes with oil drainage. This is big news! It is also very logical after S&S thought about it for a bit. Since the descending pistons violently displace air from the bottom-end compartment through the pinion bearing and into the timing compartment and finally up into the top-end compartment; why would air not also be pushed up the oil drain holes from the top end to the timing chest?

In each head and cylinder, the Evo top end oil return holes, dump oil-return into the bottom-end compartment. The Twin Cam oil return also comes down a passage in each head and cylinder but instead of dumping into the bottom end, the returning oil routes into another passage through the engine casing. This passage leads back over to the timing compartment to be scavenged and returned to the oil tank (reservoir), by the sump action of the internal oil pump.

If transferring air were interfering with this oil return process, wouldn't this cause a build-up of oil inside the rocker arm wafer covers? The S&S Reed Valve prevents air from transferring back through the pinion bearing as the pistons ascend in their respective cylinders. However, the reed valve will let air transfer from the bottom-end section into the timing compartment as the pistons descend. There will be lots more on this as I proceed.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Memories of An

Evolution Engine Case, Timing Chest – Breather Valve Chamber

Pictured is a set of bare Evolution style engine casings with a view into the right-side timing chest. There is no cam support plate like that found in the Twin Cam. The timing cover that fits onto the end of the Evolution timing chest is load bearing. The cover has a cam bushing for the single outboard-cam-journal end support. It also houses the pinion bushing that the end of the pinion shaft fits into in order for crank components to receive their crucial feed supply of bottom-end oil. The larger center hole accepts a pressed-in pinion race and a pinion bearing that supports the pinion flywheel shaft as it extends from the bottom-end cavity into the timing compartment. The smaller hole above fits with a cam bearing to support the inboard cam journal. The cylindrical breather hole to the left houses the rotary breather valve (see previous picture). In Evolution and predecessor Big Twins going back to the Knucklehead's inception in 1936, the feed oil to the top end returns via gravity into the bottom end compartment. Twin Cam top-end engine oil supply returns via gravity directly to the timing case compartment. As the pistons are pulled down their respective cylinders, vacating air created by diminishing bottom end compartment space expels scavenged oil from the flywheel compartment through the breather valve into the timing chest compartment. The breather valve opening aperture times to align with its mating opening in the engine case breather valve housing when the pistons begin their descent. Heavier oil separates from the air in the timing case for scavenging back into the return side of the oil pump for return to the oil tank reservoir. The separated air on 1984 to 1991 Evolutions continues through the vent crankcase passage out to an external oil line up to the carburetor air breather and sucks back into the combustion chamber. On 1992 to 2000 Evolutions, the separated air in the timing chest flows up the pushrod tubes through a breather apparatus in each head for further oil-separation before the supposedly-cleansed air flows out through a hollow breather tube bolt in each head into the breather cover for re-ingestion into the engine's combustion chamber. In the picture, the two holes at the top of the engine casing timing chest will house the tappet blocks, which house the hydraulic (tappet), lifters (two per tappet block) that roll over and follow the cam lobes to actuate the four separate valve trains usually referred to singly as the valve train. Located behind the tappet block holes is the front cylinder spigot hole.

The Rotary Breather Gear

I realize this first volume is about the Twin Cam but many problems have beginnings, historically in the past. Attempts to combat ongoing problems may also evolve from times gone by. If there was ever an historical problem, expelling of oil to the outside world certainly is near the top of the proverbial list.

Problematic Oil Venting

There are two main compartments in an Evolution engine where air plays an important role. Their functions are separate.

Oil venting, also known as blowby or oil carryover out of the air filter exacerbates when increasing the displacement of the engine and/or riding at sustained higher rpm. Therefore, it is no surprise that many big-inch strokers based on the Evo, Shovel, Pan, and Knucklehead engines have severe blowby problems, overwhelming their conventional rotary-breather gear system.

Increases in Swept Volume Travel Increases Blowby

Big-bore and/or stroked engines create their power by increasing the swept volume. This means that the piston has a wider diameter known as big bore, or it travels farther up and down the cylinder bore, colloquially known as a stroker. Either of these or in combination result in more air capacity as the piston sweeps a wider bore and/or longer piston travel from its bottom dead center (BDC) position to top dead center (TDC).

More air brought in because of increasing swept volume allows burning an increase in fuel, creating more horsepower and torque. Fuel and air mix to burn in certain proportions. More air means the capability of introducing and burning more fuel. This is why increasing air intake is so important for power.

Combustion Air is Separate from Internal Engine Air

The ingested air for burning fuel contains below the seated valves in the head and above the seating piston rings in the combustion chamber. This air is very much separate from the internal engine air that displaces around the inner workings of the engine. Internal engine air is kept in its locations by the sealing rings…except on the opposite sides. The pushrod tunnels and oil return top end passages connect the various engine compartments.

Internal Engine Air

Vented breathing occurs below the piston rings in the crankcase, the timing chest, and the head cavities separate from the intake/exhaust ports and combustion chambers. However, with increased engine size, there is also correspondingly more air displaced from the crankcase compartment with the descending pistons on the intake and power strokes. This bigger volume of oilified air overloads the rotary breather gear valve on Evo and predecessor engines.

The Twin Cam breather apparatus in each rocker box also has difficulty in separating the oilified mist with bigger volumes and/or sustained high rpm riding. Many times the Twin Cam breathers cannot deal with the excess scavenged oil with its increased-volume oilified mist.

Blowby, in this case defines as excess oil and oily air discharging to the outside world.

Enlarging the Breather Hole for Increased Swept Volume

At Heavy Duty Cycles, we routinely enlarge the breather exhaust port located in the cam gear compartment of the Evo and Shovel/Pan/Knuckle right-engine casing to time with the breather gear's opening to help accommodate this extra exhausted air mist. This timed hole in the casing is, of course, located in the breather gear hole positioning out towards the timing compartment.

This is specialized work, since enlarging the hole to correspond to the timing of the descending pistons is necessary. Compromises are required since different rpm levels match to differing configurations of hole size and location. This is impossible with a fixed location opening. The hole may be modifiable but not adjustable to differing conditions. Modification of the breather gear's mating hole is a viable option in some cases, so it gets even trickier for the uninitiated.

The bottom line is that no matter what modification the mechanic carries out, oil carryover to the outside world is really aggravated by bigger cubic inches and/or sustained high-speed riding. Even today's Twin Cam, the tightest of all Harley oiling systems, occasionally leaves messy oil dripping down the right side of the engine.

Rarely is it an oil leak as such that causes H-D's newest models to mark its spot since the excellent machining of mating parts combined with truly good gasketry, impervious O-rings, and seals thwart this. More likely, it will be an inability to separate venting air from impregnating oil that becomes an oilified mist caused by rapid movements of air and churning parts like the flywheels inside the engine.

The best venting system designed by the Factory found to date is on the Twin Cam; but alas, too often it proves inadequate when riding at sustained high rpm and/or when increasing engine displacement from the stock TC88 up to the very popular 95c.i. or the TC96 to 103 cubes. Of course the new stock TC103 engines and the CVO 110 engines face the same or greater challenges. However, they along with the TC96 has an oil pump that increases sumping by 23% over the TC88.

Emissions-Driven Design Changes

The advent of emissions controls that includes oil leaks, gasoline vaporization, and noise control, which began in earnest in the mid-seventies, drives Harley design.

If you think I am exaggerating, consider some of the following examples.

Rear chains made too much noise, so the enclosed, oil bath, chain drives were developed and used in the early eighties on the rubbermount Big Twins.

- This was an improvement in suppressing the noise, but the development of Aramid synthetic fibers (Kevlar), allowed for the very strong, durable, and quietest rear (belt) drive on all modern Harley's.
- One main purpose of Evolution engine development was to increase the percentage of burn of fuel in the redesigned combustion chambers to prevent as many harmful emissions escaping into the atmosphere as possible with this newer technology.
- The side effects were marvelous as more reliability and a much faster engine also ensued.
- Electrical systems needed upgrading to increase spark voltage from a meager 15,000 or so volts on mechanical points/condenser ignitions to upwards of 40,000 volts with transistorized electronic ignitions.

- This was necessary because spark plug gap increased. A wider gap is required to ignite the increasingly lean air-to-fuel ratios. Only the higher voltages could jump the gap, thereby enabling ignition. *Lean* refers to higher ratios of air relative to the amount of gas. Less gas relative to air in modern combustion chambers, helps eliminate harmful emissions, thus the electrical systems required upgrading in order to create hotter sparks to ignite the fuel.
- The whole design of the Twin Cam revolved around getting rid of the meshing gears that made too much noise in the timing chest. Silent timing chains…very different in design from the grunt chains used in the primary system and the old rear drives…were developed to lessen the assault of noise in modern life.
- Head design improved in the Twin Cams with a view to burning more of the fuel to further limit emissions. It is a superlative design, if only the ports and valves were a little bigger to increase flow for more power.
- Electronic fuel injection (EFI) begins replacing the inefficient carburetor.
- While the design is excellent from an emissions viewpoint, the heads service a bigger engine than the Evo but flow less air. We need more air to mix with more gas for more power.

Torque also gains from the improved Twin Cam head design but a lot more power can realize by making what is there a little bigger to allow increased flow.

EFI: Better Gas Mileage, Emission Reduction and its Faster!

EFI now graces every Harley-Davidson model as of 2007. The exciting thing for those of us that can adapt rather than fall by the wayside is that EFI not only reduces emissions radically, but it increases gas mileage. It even gets better for the performance crowd.

EFI, for those in the know, beats carburetors easily for wild performance increases.

Engine venting also evolves and changes the modern Harley as a direct result of pollution control requirements.

In short, the modern H-D looks like it does because of design changes required to meet ever-increasing noise and pollution controls dictated by American and European governments with other industrialized nations like Canada tagging along. To Harley-Davidson's credit…at least up until now…it has maintained the basic shape of the V-twin engine that we all love.

Future Changes

The reader is going to get sick of me talking about future H-D design.

- Look forward to water jackets around our beloved engines with radiators.
- Head design can go a couple of different directions, whether it is more valves per cylinder or more cylinders!
- Overhead cams will eliminate the inefficient valve train.
- Cylinder angularity will increase from the traditional and inefficient 45^0 to 56^0 or 60^0.
- Chrome pushrod tunnels will stay, I am sure, but will be decorative.

However, no matter, which way H-D is forced to go, venting will always be a major issue since the Factory has not yet fool-proofed this malady. Harley has made huge strides over the years but has not quite got there yet.

The aftermarket has made wonderful advances, some of which may be adopted by the Factory over time. I would guess that H-D will be adapting some of these already developed methodologies by great aftermarket developers and producers like S&S Cycle, TP Engineering, and Doherty to name a few prominent ones in this specialized area.

Late-Evo Venting Improvements

Harley started to get serious with the Evolutions in designing new venting systems and they have improved with time. However, the beast still marks its spot.

The 1992 to 1999 Evolutions vented and breathed in the same way as the 1984 to 1991 models with one major exception. Instead of the vent from the crankcase going up to the air breather, the later models differ in their breathing system in that the oily mist vents internally through the rockers into the air breather.

During 1992 to 1999, crankcase air vents up the pushrod tubes driven by the downward pistons to a rubber umbrella one-way valve in the middle rocker box section. Oil for the most part, carried by this air mist separates at this stage. The oil flows away via a small drain hole in each cylinder head back down into the crankcase.

The mounting bolts for attaching the air breather backing plate to the heads are hollow. The air passageway leads to these hollow mounting bolts to allow the air to travel into the breather. The vacuum created by the downward pistons on their respective intake strokes suck in this vented misted air along with the fresh intake charge.

Once again, this is not an ideal way for an engine to function and is a definite impediment on performance engines, but it works well in decreasing emissions.

Puking Gravity Feed Oil Tanks

Gravity Feed Oil Supply

First, let's look at oil tanks and the oil pumps that they feed. How is it possible that the oil tank may be partially responsible for pools of oil on the ground below the engine's venting system? The nature of the gravity feed oil tanks still used on the Softail model series where the oil tank is located above the external oil pump is an aggravating factor. The problem is pervasive on 2000 and earlier Evolutions and all that went before. Sportsters also suffer from this malady. Evo models that moved their oil tanks underneath the transmission did much to eliminate this possible situation.

The Gear-Driven Oil Pumps

The resultant gravity-feed oil deposits center around the inability of the oil pump-check valve to stop gravity leakage from the oil tank above into the bottom-end cavity inside the engine.

- Briefly, this check valve in external oil pumps is simply a small individual round ball bearing that sits into a mating seat. The pressure of the oil above holds the bearing in its seat, supposedly preventing leakage downwards.
- Even when the mating surfaces of both bearing and seat were perfect, over time the oil will work its way by if the bike is left sitting for a few days or weeks without starting.

The regular starting of the Big Twin or XL allows the return-side of the oil pump to do its job and pump small amounts of excess of oil back into the oil tank where it belongs.

Puking Oil Syndrome

Given time, the gravity feed oil tanks drain into the bottom end. When too much oil feeds down and settles into the bottom of the engine casings, it becomes unwelcome upon start-up. The powerful moving flywheels cause the expulsion of excess oil out the area of least resistance before the sealing piston rings are overwhelmed. This, of course, is the vent to the outside world.

Eliminating Gravity-Feed Oil Tanks

All Twin Cam A (Alpha), models, which are the Dynas and the Touring FLHT Baggers, do not suffer from this aggravation because their oil tanks locate under the transmission. The oil pumps into the engine upwards on a slight grade. Gravity in this case helps keep unwanted oil out of the engine.

We have now discovered another Harley-Davidson design change predicated on the EPA requirement to eliminate oil deposit emissions. However, traditionalist styling prerequisites surely stopped this redesign from affecting the Softail models so dependent on mimicking the old rigid frame Knuckle and Panhead look with their wraparound gravity-feed oil tanks.

Sportsters currently have no available space to relocate the oil tank below the engine. However, the gravity feed oil pump design has been improved on both these models. While reducing venting onto the ground because of a deficient check valve, it still happens in varying amounts.

The Twin Cam Beta Oil Puking Solution

Let's examine the Twin Cam 88B (Beta), Softail models. Once upon a time, before 2000 nearly every Softail stored over the winter would puke oil out of the vent in my shop before spring start-up. Almost every Evolution FXST/FLST still does to this day.

In the shop, we know this and prevent a huge mess by first refilling the oil tanks three-quarters full in the spring and by placing a drain pan under the vent. Upon start-up, fresh oil feeds into the engine, some oil trapped in the bottom end pumps back to the oil tank, and the rest of the excess oil is pumped out the vent and into the drain pan.

Twin Cam Softail Oil Feed Sequence

Oil feeds down from above via gravity through the oil line that feeds into the input side of the cam support plate.

If the engine is running, the oil will feed through to the feed side of the oil pump geroters.

I will look at a running oil-feed situation first and then discuss what can happen if the bike is at rest for a long period. The cam support plate is the directional distribution supply line(s) for the whole engine. The ensuing description of this process will seem like the oil crosses back and forth and up and down the cam support plate in complicated fashion to supply the lifeblood of the engine.

The Heart, Arteries and Veins that Supply Engine Oil

The oil pump is the heart of the engine; the cam support plate houses the arteries, and the return drain holes mimic veins.

- Once in the feed supply side of the oil pump, the oil feeds back into the support plate and pushes uphill in a channel to the other side of the cam support plate where it pumps into the oil filter housing.
- All of the pumping and feed action is still below the gravity pressure of the oil tank. The effect of gravity ceases as oil begins travel to the rocker boxes in the top end.
- However, at this point, gravity begins to assist in oil return.

The H-D Oil Filter

- The oil now supplies through feed side of the early 10-micron or later 5-micron synthetic media oil filter and then out the return side of the filter to feed back into the cam support plate. This feedback into the plate is about 1 ½" above where the oil feeds out of the plate and into the oil filter housing.
- In 2006, Harley-Davidson introduced the 5-micron oil filter, which filters a percentage of the oil-dispersed particulate above five-millionths of a meter. It does not get much better than this.

The rating of an oil filter is a complicated concept although the rating makes it seem so simple. No filter removes all floating particulate carried to it. To complicate things further, there are different rating formulas and differing conditions for performing the rating tests.

Therefore, comparing filter micron ratings and what that actually entails can be a daunting process. However, know one thing! Harley-Davidson is steadily improving oil filtration over time from the great-in-its- day 30-micron pleated paper Evolution filter to the Twin Cam 10-micron pleated synthetic media filtration and now doubling filtration to a 5-micron rating.

Five microns, no matter the complicating rating factors is very good; the best ever achieved by the Factory. Pleating the synthetic media filtering material gives exponentially greater filtering surface area for the oil to flow through.

Feeding the Engine's Lifeblood

Oil feeds under pressure from the oil filter outlet; about 1" diagonally up across to near the top of the cam support plate in an internal passage to first supply the front lifter engine case housing, then the hydraulic lifters. The passageway then continues horizontally about 4 ½" across the top of the cam support plate to feed the rear hydraulic lifter. The reader can refer to different pictures of cam support plates in this volume where many internal oil passages may be detected externally by the berms or raised furrows on the cam support plate inboard and outboard faces.

1. Half way between the two-lifter feeds, another channel branches off at 90-degrees and feeds directly down to two pin-sized oil outlets.
2. The upper one sprays and lubricates the secondary cam chain on the inboard side of the support plate.

3. The second and lower pinhole sprays oil onto the pinion primary-drive sprocket and therefore the primary chain driven by it. This pinhole obviously feeds on the outboard side of the cam support plate where these parts are located.
4. Accomplishing the spray effect is via a relatively huge supply passage full of oil under pressure squirting out of the tiny pinhole-size oil-distribution outlets. The weight and pressure of the oil forces this. Oil would only seep out of these holes otherwise.
5. About 2 ¼" down from the top horizontal hydraulic feed oil passage and between the pinhole chain-sprocket feeds, another oil passage diverts from the second downward oil passage.
6. Connecting to and fed by the pressurized down tube passage this new passage travels about 3" to the left on the rear side of the support plate.
7. It enters another connecting passage in the engine casing, leaving the support plate to feed the TC88B, TC96B counter balancer tensioners. This feedhole is unnecessary and blocked on the TC88A and TC96A engines since they are rubbermounted and lack counterbalancers.
8. After supplying the counterbalancers and hydraulic adjusters, the oil is now at a feed dead end. This oil will now enter the return side of oiling system after splash lubricating the balancer chain components.
9. Let's now go back to the downward vertical passage from the horizontal engine hydraulic lifter passage. The oil still goes down about three-eighths of an inch farther than previously discussed for a total of a 3 ¼"- long passage to feed oil into the pinion shaft bushing in the cam support plate.
10. The pinion-bushing channel directs this oil and feeds it into the crank pin and the bottom-end bearings.

The next piece of information is quite extraordinary since it is a total departure from anything ever used on a Harley in its entire history from Day One in 1903. This information is largely unknown because Twin Cam flywheel assemblies are currently not rebuildable as there are no individual parts. The crank pin is hollow! Most are unaware of this fact since the Twin Cam, as a base for reliability very rarely needs to rebuild this component crank assembly.

I will continue oil feed, oil return, filling crankcases and puking oil after a few short digressions in section *Twin Cam Oil Pump Seepage at Rest* a little later in this chapter.

Twin Cam Flywheel Problems

Harley technicians are taught to replace the whole flywheel assembly unit if necessary, which it rarely is.

1. I will qualify the above statement since some have needed replacement because of the internal floating thrust washer(s) chewing between the flywheel halves and the connecting rod/bearing cages around the crank pin.
2. Others have needed replacement because of the pinion half not trued correctly with the sprocket flywheel side with a resultant out-of- true pinion shaft.
3. In the worst case I am aware of without flywheels actually scissoring, the pinion shaft had a confirmed runout of up to .009". I will discuss the devastating effects of scissoring flywheels in *Volume II: Performancing the Twin Cam,* Chapter V*: Twin Cam Vibration, section, Internal Cause of Vibration: Flywheel Runout.*

4. More than .002" pinion shaft runout will begin premature wear on the oil pump. The oil pump supported on the pinion shaft, bolts to the stationary cam support plate. Something will give, which will always be the weakest part(s) and that will be the oil pump with its close-tolerance fitment and the pinion bushing in the cam support plate.

The pinion shaft end that protrudes through the pinion bushing in the support plate will enlarge the relatively softer bushing. A close tolerance is required here as oil feeds through this bushing into the pinion shaft and needs pressure to reach its goal of the crank bearings. A sloppy and enlarged fit will reduce oil pressure to the heart of the engine.

In our experience at Heavy Duty Cycles, out-of-true flywheel pinion shafts are usually in the .003" to 004" range.

Of course, most flywheels true very accurately and the majority of TC88 crank assemblies obviously present no problems at .001" runout or less. I wish I could say the same for TC96, TC103, and CVO 110 flywheels.

Sprocket Shaft Bearings

Another cause of flywheel replacement evolves from the replacement of the tried- and-true opposed-tapered Timken sprocket shaft end bearing assemblies circa 2002 with the huge ball bearing (24004-03, 2400403A, and 24605-07), the same as used to support the pinion shaft side of the crank. This change presented the Factory with endplay issues of the flywheels and initial resultant damaged compensator/alternator parts attached to the end of the sprocket shaft. Endplay is serious stuff as the crank can wander back and forth inside the engine casings eventually blowing up the engine if contacting the engine case sides.

Other than the above-mentioned cases, the flywheels have been the most reliable ever in the history of Harley. It just does not feel that way when it is your flywheels acting out.

Twin Cam Pinion Bearing

The pinion right-side engine case support bearing for the right-flywheel pinion shaft is a humungous roller bearing first used in 1999 on the Touring FLHT and Dyna Twin Cam 88A models. The bearing has an outer diameter (OD), measuring approximately 2 ¾" with an inner diameter (ID), of about 1 $^{11}/_{16}$".

The A in 88A is short form for Alpha and B is for Beta. They are used to distinguish the externally rubber mounted "A" engines from the internally counterbalanced "B" models.

The 1999 to 2002 pinion bearings used in the Touring and Dyna Alpha engines (24623-99, 24623-99A, and 24623-99B) represent two additional refinements to the same basic bearing.

The part number without a letter (24623-99) attached to the end is the first bearing used by Harley-Davidson beginning in 1999. The first change to the 24963-99 bearing was to combat a whistling noise. This was accomplished by reducing the fitment of the roller in its cage from approximately .006" to .022" after Sept 25, 1998 to between .002" to .008". This refined bearing identifies as a 24963-99A.

A further enhancement resulted in the bearing nomenclature to change to 24963-99B. Thus the three 24623-99 bearings were used in all Touring and Dyna Alpha engines from 1999 to 2002 until the introduction of the smaller 24604-00 series of bearings that also has gone through continuous refinement.

I have never seen one of these earlier larger bearings wear out in a properly cared for engine. The times I have replaced this Twin Cam pinion bearing was due to other parts selfdestructing whose debris infected these rolling behemoths. Timing chest components are the usual suspects for infectious debris.

The Factory began using a smaller but still large pinion bearing, the 24604-00 series with the introduction of the Softail Beta engines in the year 2000. Use of this large but relatively undersized bearing began in 2003 on both Touring and Dyna models. This roller bearing has a 2 $^{9}/_{16}$" OD and an ID of 1 $^{11}/_{16}$". The inner diameter is the same as found in the 24963-99 series bearings because they both support the same size outer diameter pinion shaft.

Twin Cam Pinion Shaft Bearing History

Year	Dyna 88A and 96A	Touring 88A and 96A	Softail 88B and 96B
1999 early	24623-99	24623-99	NA
1999 late	24623-99A	24623-99A	NA
2000	24623-99B	24623-99B	24604-00
2001	24623-99B	24623-99B	24604-00
2002	24623-99B	24623-99B	24604-00A 24604-00B
2003	24604-00B	24604-00C	24604-00C
2004	24604-00C	24604-00C	24604-00C
2005	24604-00C	24604-00C	24604-00C
2006	24604-00D	24604-00D	24604-00D
2007	24604-00D	24604-00D	24604-00D
2008	24605-07	24605-07	24605-07
2009	24605-07	24605-07	24605-07

Twin Cam Sprocket Shaft Bearing(s)

The left-side engine case bearing(s) support the left flywheel sprocket (power) shaft. The pre-2003 HD-9028 bearing sets are inward-facing tapered Timken bearings consisting of two races and two bearings with a crank end-spacing shim between them. The shim determines endplay of the flywheel assembly. Endplay is how much the flywheel assembly can float back and forth inside the engine casings. The sixteen different sized shims vary in size from .0895" to .1195" in successive gradients of 20-thousandths of an inch (.020"). Successfully used in all Big Twins from 1956 to 2002 these long-lasting bearings kits are very durable.

The 24604-00B, 24604-00C, and 24604-00D bearings are a big roller bearing measuring 2 $^{9}/_{16}$" OD and an ID of 1 $^{11}/_{16}$". They are well suited for the up and down vertical pressures imposed both on the pinion and sprocket side shafts of the crank extending through the engine casings. However, I feel they are ill-suited for the lateral horizontal-pulsing power surges traveling sideways from the crank to the primary compensating engine sprocket.

Twin Cam Sprocket Shaft Bearing History

Year	Dyna 88A and 96A	Touring 88A and 96A	Softail 88B and 96B
1999	9028	9028	NA
2000	9028	9028	9028
2001	9028	9028	9028
2002	9028	9028	9028
2003	24604-00B	24604-00C	24604-00C
2004	24604-00C	24604-00C	24604-00C
2005	24604-00C	24604-00C	24604-00C
2006	24604-00D	24604-00D	24604-00D
2007	24604-00D	24604-00D	24604-00D
2008	24605-07	24605-07	24605-07
2009	24605-07	24605-07	24605-07

The Hollow Crank Pin

I took a flywheel assembly apart just to see what was going on in 2007. I did this because shops had not started to rebuild Twin Cam cranks even nine full years after their inception. The majority of them are so reliable there has been no need. By the time we were nine years into the Evolution engine, we had probably rebuilt a hundred bottom ends of this vintage at Heavy Duty Cycles. My initial observations were striking.

1. First, the assembly comes apart hard. It is much easier to disassemble a crank held together by crank pin nuts found on all previous Harley's.
2. The crank pin has the same diameter its whole length. It does not taper at either end as all other modern predecessor Harley crank pins do.
3. Neither is there a centering keyway. Most other H-D engine flywheels have a half-moon shaped Woodruff key that fits in a half moon-shaped indent in the crank pin and a flat-cut indent in the pinion shaft flywheel to locate and secure the crank pin's fit into the flywheel half. Location is extremely important as the key ensures alignment of the pinion and flywheel oil feed with its mating crank pin oil-feed hole.
4. The straight non-tapered ends of the Twin Cam crank pin are .007" interference press-fit into each flywheel side.
5. The size of the straight, three-hole oiling crank pin is impressive. Its outside diameter is a full .420" bigger than the diameter of that now skinny single oiling hole crank pin used in the Evo.

Even if wanting to rebuild a Twin Cam crank, there are no parts offered to do so. H-D has no listing for separate crank parts. They only sell the flywheels as a complete unit.

Therefore, I had to take a set apart to see if I had missed anything. Guess what, I had!

1. The 1 ⅝"-diameter crank pin has a feature that few know about. The crank pin is not solid steel but is in reality a hollow tube! Mind you, it is a very strong and supportive hollow tube.

2. Each end of the crank pin plugs with steel caps that are pressed into the hollow ends, thereby creating a sealed internal reservoir.
3. This new-type crank pin is still very much stronger than what went before.
4. There are three oiling holes inside the crank pin, one each to lubricate each set of bearings.
5. There are two separate female bearing sets and individual oiler for each female connecting rod big end. The third (middle) oiler is for a wider bearing set sitting in the middle of the two female sets for the male connecting rod big end.

The male rod needs wider bearings for support because it is an individual rod whereas the female connecting rod is forked, thereby giving it a more secure and balanced support base.

1. Oil feeds via the feed side of the internal oil pump in through the pinion shaft bushing in the cam support plate and into the pinion shaft oiling passage itself.
2. The pressurized oil travels across horizontally through the pinion shaft and into the right flywheel half.
3. It then flows up an internal channel and is delivered into the hollow part of the crank pin.
4. A mating hole in the crank pin intersects with the oil passage in the flywheel.
5. The pressed-in crank pin in each flywheel attaches them together as one unit. The tight .007" press interference fit prevents shifting, which would block the oil feed passage.

The shafts locate in the center of each flywheel while the crank pin always offsets towards the flywheel rims to create the stroke. If the crank pin were located in line with the flywheel shafts, the pistons would remain stationary in their respective cylinder bores as the crank rotates.

This crank pin offset determines how far up the cylinders the rotating flywheels will thrust the connecting rods and their attached pistons and then pull them back down. The pistons will reach top dead center (TDC), when the crank's offset crank pin is at the vertically twelve o'clock highest position. The pistons will center in the cylinders when the crank pin is at the three and nine o'clock positions. The pistons will reach bottom dead center (BDC), in the cylinder bores when the crank pin reaches the lowest six o'clock vertical position.

When the crank pin's inside hollow reservoir is full of oil, pressure from oil still being delivered into the crank pin will force the lubricant out of the three oiling holes to feed each set of three bearing cages with eighteen roller needle bearings each.

The purpose of this largely unknown reservoir has an ingenious simplicity, which is cooling.

Twin Cam Oil Pump Seepage at Rest

Let's return to the oiling paths of the Twin Cam TC88B engine. How might oil seep into the bottom end when the bike is at rest? Surely, it must be more difficult with an internal oil pump and the filter running interference.

If the TC88B engine is not running, it is possible for the gravity feed oil to work its way slowly, over time, through the same process of oil distribution but without the oil- pump-geroters-driven pressure. Over a prolonged period of inactivity, it is possible for oil to make its way through these various passages.

The oil will feed out into the timing cavity quickest through the two-pinhole primary and secondary chain feeds in the cam support plate. These are the paths of least resistance.

1. Oil will also bleed down past the hydraulic lifters into the timing compartment.
2. Oil will lastly enter into the timing chest past the hydraulic adjusters that tension the counterbalancer chain.

3. Once the timing chest compartment fills up a couple of inches to the level of the bottom of the huge pinion bearing separating the timing chest from the bottom-end compartment, the oil can drain into the bottom end cavity, once again via the physical force of gravity.

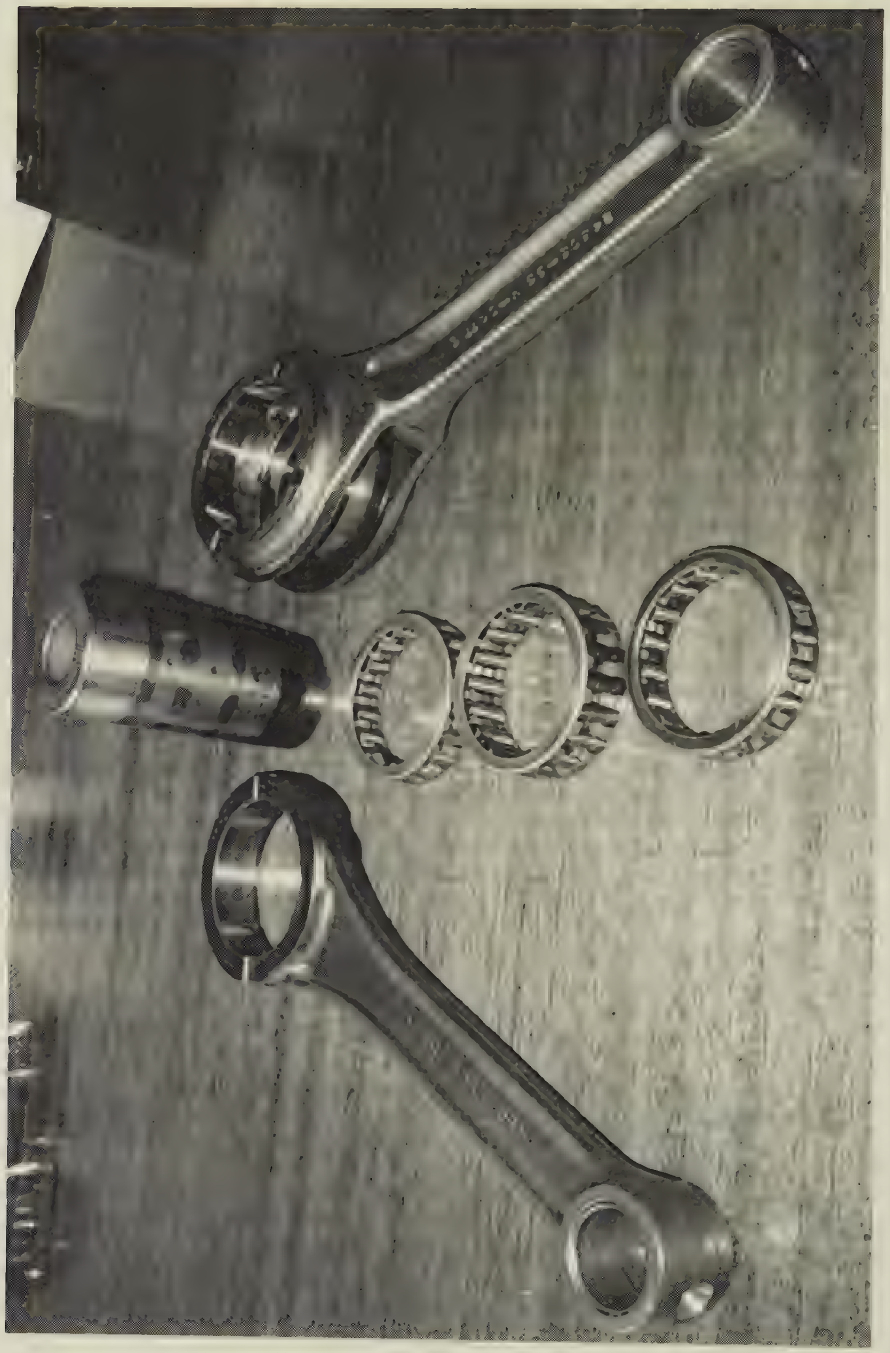
Oil that feeds through the pinion shaft into the hollow crank pin reservoir and through the three crank pin oil holes will also drain directly into the bottom end especially if the feedholes point down. It would still feed out if the holes were above horizontal if the bike were resting on its sidestand. The position of where the crank stopped when the bike was last turned off will dictate in which direction the crank pin oiling holes will be.

The pressure from the gravity feed oil tank will ensure the oil's eventual drainage. This scenario plays out especially well if the bike is stored in a warm garage as opposed to a cold one, where oil viscosity will severely retard but not stop oil flow. For the naysayers, a winter stored TC88B in my back shop filled up with gravity- fed oil in both the timing compartment along with the bottom end not long after the TC88B Softail was introduced in 2000. I discovered this happening by accident when I took the cam cover off to install a gear drive. An abundance of oil that should not have been there flowed out onto the ground at my feet. I then checked the oil tank, and it was almost empty.

What would have happened if I tried to start it? There is no danger of a lack of oil. The super-lubricated engine will wet-sump in the excess oil.

1. Trust me; the rider will turn the bike off immediately after discovering oil puking out over the side of the bike. This would not happen to me because I would have checked the oil level first and discovered it missing.
2. However, most riders do not perform this necessary check, and they will experience oil gushing out the top-end vents into the breather and then all over the side of the bike onto the ground.
3. If the rider did check and discover the lack of oil in the tank, he or she may reasonably refill the tank before trying to fire the bike. Many do not initially ask themselves the question of where the oil disappeared to, as there is none under the bike.
4. In this scenario, the pump will return some of the extra bottom oil back into the oil tank where there will now not be enough room to accommodate it.
5. As always, the weaker part will give way. In this case, the pumping oil will force the push-in cap to become a projectile. Oil will then escape once again down the side of the bike except to the rear by the oil tank this time. This oil-cap release could occur during start-up because the oil pump activates as soon as the engine turns over. More likely, if the bike started it would pop soon after the ride started as pressure kept building. I have seen these push-in oil caps fly a good fifteen feet in the air.
6. Another scenario could occur, which is spark plug fouling.
7. The churning flywheels would throw so much excess oil up into the cylinders that the sheer volume could overwhelm the rings, blow by them, and foul the spark plugs.
8. Spark plugs fire when the electricity jumps across the electrodes. Oil will cover the electrodes, bake on, and prevent the flame arc. Oil fouling will result in a shiny black and scaly residue on the electrodes. This is easy to distinguish from gas fouling, which leaves a flat black fluffy residue.

In conclusion, gravity-drainage problems largely ceased with the introduction of the Twin Cam with the internal oil pump redesign. The oil tanks on all models except the Softail series are no longer gravity-feed but located underneath the transmission.



1999-2006 Twin Cam Crank Pin, Connecting Rods, and Bearings

Pictured are a Twin Cam crank pin (middle left), 1999 to 2006 male (bottom) and female (top) connecting rods with two narrow sets of female bearing rollers and bearing cages, and one set of wider male rollers and cage (middle center-to-right). Constant pressure from the internal oil pump squirts oil from the hollow crank pin's reservoir into their mating bearing cages and rollers through the crank pin's three oil feedholes. Out of sight is the oil feedhole into the crank pin from the pinion flywheel. Oil pumps into the cam support plate to the pinion shaft bushing, into and through a passage in the pinion shaft for delivery up into the pinion flywheel passage and into the crank pin. The end caps are missing from the crank pin ends that create the cooling reservoir. The wear marks are normal for many miles and result from roller action, heat, and baked-in oil stains. However, I would always use a new crank pin, rollers, and serviced connecting rods if I rebuilt this connecting rod set when parts become available. The connecting rods look the same as Evo's, just very much bigger and stronger. All predecessor H-D con rods have rod races pressed into the three big ends for the roller bearings to "roll" on. Twin Cam big-end rod races are made from parent-material-bearings that are hardened to withstand the rigors of the fifty-four bearings (eighteen per cage). *A parent-material-bearing* is a tricky phrase as it simply means that the material of the connecting rod itself is bored, heat-hardened and then honed to size to become the bearing surface. The uninitiated might think Twin Cam rods need replacement because of a purplish hue to the metal around the big ends and extending a little up into the shaft of the rods from the heat treatment. If seeing this on Evolution connecting rods, it would indicate heat distortion requiring replacement. The *captured* three sets of eighteen needle rollers in copper-coated cages are supportive, which help break-in procedures, durability, and offer easy wear-spot identification. There are three more bearings than in the Evolution and late Shovelhead engines; although the bearings are the same diameter, they are longer. Partnered with the wider set of bearings is the wider male connecting rod with its parent material bearing (race). The single-fork male connecting rod faces the front of the engine and services the front cylinder and piston. The dual-fork female connecting rod services the rear cylinder and piston. The wrist pin, bushing, and hole-size in the connecting rod small ends are much larger and beefier than on previous models.

Defining Blowby, Oil Carryover, and Venting

Blowby, venting, and *oil carryover* are terms used to describe different phenomena, but the basic idea or concept in each has commonality. Quite often, the terms are interchangeable and are synonymous with each other. Sometimes they refer to different phenomena. The terms must be read in the context they are used.

It is simple once one has their head wrapped around the concept of a gas or fluid going somewhere not intended. Blowby or oil carryover, just means that a gaseous mixture, liquid gas, or oil penetrates a restricted area.

Blowby into the Combustion Chamber from the Bottom End

Just earlier, I gave an example of blowby with the rings being overwhelmed with more oil than they were capable of blocking. Oil is not supposed to enter the combustion chamber.

Blowby into the Bottom End from the Combustion Chamber

Combustion gases may overwhelm the rings from above and blowby into the Bottom end.

Air Venting into a Vacuum

Venting usually has to do with the physical principle of a vacuum; for example, where air needs to replace a fluid draining out of a sealed container like gasoline draining out of a gas tank to feed the fuel induction system. Air needs to vent into the gas tank to replace the volume of gas draining out. Oil leaving an oil tank to lubricate the engine also requires air to vent in to replace its draining volume.

A vacuum occurs since a cap seals either tank. Air must fill this vacuum or gas/oil flow will impede. In this case, the tank will vent by air filling the vacuum left behind by the departing liquid.

Internal Engine Air Venting

I have also talked about engine venting, where internally moving parts displaces inside air. Some air vents out of the engine. Remaining air vents back in to fill vacuous areas vacated by parts moving in another direction. The best example of this is ascending pistons venting in air to fill a vacuum as the bottom end compartment grows in size. Descending pistons reduce bottom end compartment size thus forcing air to vent out.

Blowby may also mean the transfer of oil out of the engine into the outside world. The blowby gases comprise mainly of air with suspended oil molecules that vent out of the engine.

Oil Blowby with Venting Air

Sometimes this oil vapor in the venting air liquefies and deposits into the air breather to drain out of it onto the engine's side. This is a form of blowby resulting from vented gases.

Extreme, but common, cases occur with the breather apparatus locating in each rocker box at the top of the engine overwhelming with liquid oil. In this case, the oil carryover or blowby into the breather will have much more dramatic effect as the beast marks its spot much more authoritatively.

Carryover Past the Valve and Guide Interface

Oil blowby or carryover can also occur down the valve guides past the valve stems and into the combustion chamber. While, this technically is blowby or carryover, not many refer to it in this way. In practice, normally one would refer to this scenario as oil leaking by blown valve seals and/or worn guides.

Harleyese Dialects Confuse the Novice

The last point I will make is that different geographical areas develop their own mechanical language. The Harleyese vernacular has many dialects, all of them interesting. If you view the sentence or paragraph as a whole, without dissecting it a little, the concept may seem difficult to grasp. Again, look at the vernacular used. It will be descriptive. View it in the context it is used and everything will unfold.

Modern Engine Venting Breathers

In 1992, the Factory mercifully relocated the vent to two positions; one in each head, where the umbrella valve and separation chambers allow displaced air-vapor to escape into the top of the breather. These vapors then suck into the combustion chamber for more complete combustion in the best attempt up to that time in controlling harmful emissions and annoying oil deposits. The only problem is when there is inadequate air and oil separation, Harley once again makes its mark, all over the side of the bike.

Gravity, again, is supposed to assist in separating the heavier oil from the expelled vapors before making its way all the way up into the head as opposed to just dropping out onto the ground, as was the case with earlier models.

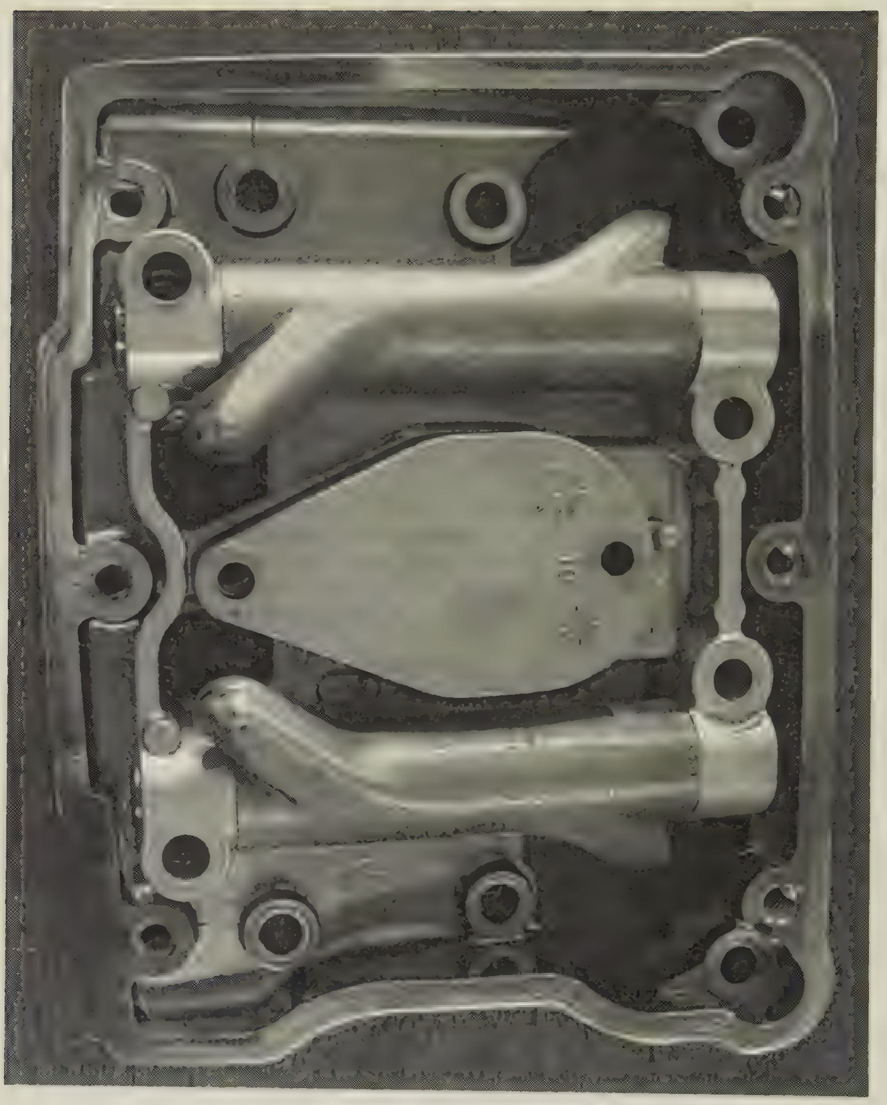
The Twin Cam 88, TC96, TC103, and CVO 110 have attempted to address this ongoing problem with a three-stage oil/air separation unit. It does work better than the similar 1992-1999 Evo system.

The TC96, TC103, and CVO 110 further refines its oil sumping by increasing oil pump return by 23% over the TC88 oil pump. If there is less oil lying around at the bottom of the engine cavities, then there is less oil to mix with transferring air that sometimes overwhelms the breather.

The Twin Cam breather apparatus locates inside the wafers on top of the heads between the rocker arms. After separation, the air vents along a tortuous path into the air breather. It draws into the combustion chambers for burning those nasty emissions. *Tortuous* is an engineering term for a convoluted pathway that encourages any oil to further separate from the exiting air.

Controlling engine oil blowby has been a constant and irritating problem for Harley-Davidson ever since the mindset changes in peoples thinking about environmental concerns.

1. The gaseous air displaced by the downward traveling pistons on the intake and power strokes of the four-cycle engine forces up the four-pushrod tubes into the two heads.
2. Each umbrella valve, which is part of the breather system, locates in the middle of the lower rocker cover wafer in each head between the pushrods and rocker arms.
3. The oily mist goes up through the one-way umbrella valve into a depressed separation area where gravity once again assists in further separation of the oil and the air.
4. Theoretically, only the remaining air vents out through a raised hole down into the carburetor breather.
5. The two vents, one for each head is seen externally as the two big bolts that screw into the heads, right and left, near the top of the inside breather plate and into the air box. The bolts are hollow to allow the gases' flow-through access.



Twin Cam Oil-Separator Breather Apparatus

Pictured is the bottom wafer (17573-99A chrome) of a Twin Cam rocker box cover that bolts to the head. The separate rocker arm support (17594-99) sits on the rocker box also bolting to the head through the wafer. This support holds the two rocker arms (17375-83A, 17360-83A) with rocker arm shafts (17611-83 x 2 not visible) that slide through one end of the support, the rocker arm center, and then into the other end of the support. The two right side rocker arm appendages (as pictured) push down on the valves, one for opening the exhaust valve and the other for the intake. The two left side ends of the rocker arms are actuated by two pushrods (one for each) whose balled ends fit into each rocker-arm cup. In between the rocker arms is the breather apparatus (17650-02 with casting number 10), whose function is to separate oil from venting air before the air vents out of the heads and into the breather for re-ingestion and burning in the combustion chamber. There is one breather apparatus locating in each head.

Enlarging Drain Hole to Assist Venting

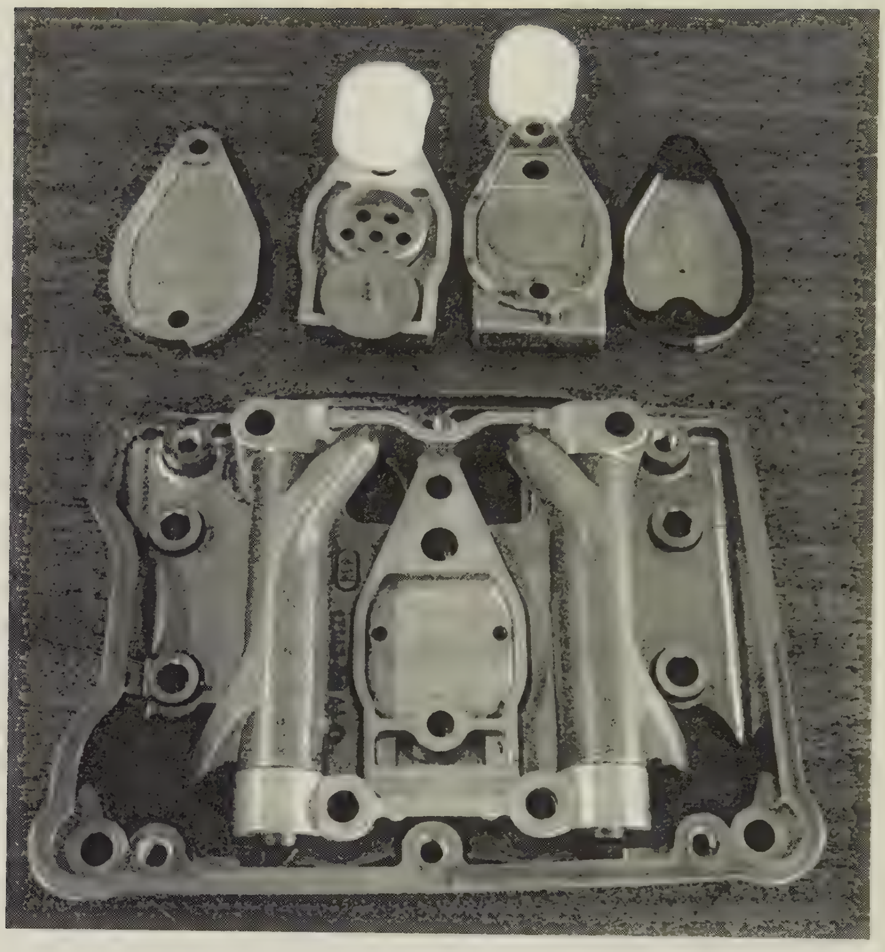
A little trick will help if the Twin Cam heads are off your bike for any reason. The separated oil in the depressed middle wafer area flows via gravity through a small drain hole. In a perfect world, tricks are not required.

While double-checking the umbrella valves for hardening and cracking, Harley-Davidson recommends drilling out the drain hole to drill number size-42, which is ninety-three thousandths of an inch (.093") in size.

1. I recommend drilling this hole out another ten-thousandths of an inch to .103".
2. I sometimes go up to one hundred and ten-thousandths of an inch (.110"), with this sizing on problem bikes. I have done this on my own bikes with great results.

I do not advise going any larger as it is easy to make a hole larger but very difficult to decrease its size. This simple assist helps ensure there is no build-up of oil waiting to drain that might overflow into the breather hole and down into the air box and out all over the engine.

As much an improvement as this new Twin Cam breather apparatus is, oil carryover out these hollow bolts and into the air breather still present a problem on some Twin Cams, especially when riding at a sustained higher rpm and/or building in more cubic inches, such as installing the 95" kit on TC88's and 103" kit on the TC96's.



Twin Cam Oil-Separator Breather Components

Pictured is a disassembled Twin Cam breather apparatus (17650-02). In previous Harley Big Twins, a rotary breather gear located in the timing chest brought oil from the crank compartment into the timing area for pick up by the return (scavenge) side of the gear-driven oil pump. The Twin Cam eliminates this breather gear as it is no longer necessary. Twin Cam top end oil return flows into the timing chest rather than the crank compartment like on the Evolution, Shovelhead, Panhead, and Knucklehead. Dual scavenging from the new internal oil pump eliminates further need for the former breather gear. Any oil in the bottom end flows via gravity through a sump to be picked up by one of the oil pump's dual ports. The other port scavenges timing chest oil for return to the oil tank-reservoir. In the Twin Cam, the whole breather venting separation system moves into the rocker boxes similar to the 1999 to 2000 Evolution models. The obvious first advantage is that gravity will assist in separating the heavier oil from the gaseous oily-air as it travels up the pushrod tubes into the breather apparatus in each head. However, the process needs more help than this initial gravity separation. The Twin Cam breather is a three-stage separation system. An open cell foam element (63815-99) shaped like a 1"-long barrel, scrubs oil from the air (two are shown in the picture but only one-per-breather-apparatus is used). It is very porous and air can easily go through the foam. The flapper valve (26858-99) is a rubber, umbrella-shaped, one-way valve that lets air out of the breather apparatus but will not allow it to travel back. A similar part also exists in the 1992 to 2000 Evolution engines but if overwhelmed will let the errant oil out along with the air. The oil separator baffle (17596-99) that the flapper valve sits in allows separated oil from the air return via gravity to the timing chest. The baffle plate is shown top, 2nd from the left with the flapper valve and foam element sitting on top. It helps separate oil by making the oily-air follow a tortuous path causing the lighter gases including air to separate and escape. All three components fit together and bolt into each head through rocker arm support (17594-99) and the lower rocker box (17573-99A chrome) in between the rocker arm assemblies. Once the gas separates, it flows out a channel machined in the heads to the outside world inside the air box breather only to suck back into the combustion chambers and be burned for emissions purposes.

The Real Problem: Disrupted Oil Return

I don't think H-D has addressed the real problem, which is air displaced by the descending pistons disrupting return oil flow from the heads back down into the crankcase. This causes an oil build-up in the heads that sometimes overwhelms the breather apparatus whose function is to separate the oil and air for venting purposes.

It becomes easy to understand why increasing cubic inches can be an aggravating factor since more air displaces when the pistons descend on the intake and power strokes. Ditto with sustained high rpm, since there is increased movement over a period of time to disrupt more return oil flow, causing a backup in the heads.

S&S Cycle, Inc. has scientifically determined an actual reason for blowby.

Digital Signal Processing Dynamometer

S&S Cycle, Inc. used a digital signal processing dynamometer (DSPD), to determine this reason for blowby. The DSPD is a specialized engine dyno not to be confused with a rear-wheel dynamometer. The engine runs independently on the dyno without the chassis.

Installation of pressure sensors in the three compartments, the crankcase, timing chest, and rocker boxes of problematic Twin Cam test engines will track pressure differences. It was no surprise to find a rise and fall in pressures in the three compartments. This, of course, is due to the ascending and descending pistons. This we already know. In big-inch Twin Cams, modest 95-inchers, 103-inchers, CVO 110's and/or in bikes that are ridden at sustained high speeds this transfer of air is increased both in volume of air and rapidity of transfer.

The DSP dyno discovered previously unknown information on where some of the air transfers. We already knew that the displaced air goes up the pushrod tunnels. Not surprisingly, it was discovered, that air also transfers through the oil return passages from the rocker boxes back down into the timing chest. More importantly, tests found that displaced air transfers upwards through the oil return passages, depending on piston stroke.

So, why is oil return transfer a concern? Well, if air were just transferring down it would assist in oil return. Air pushing up the oil return holes can and sometimes does retard oil return. Testing determined that varying amounts of oil does not return but just goes up and down with the pressure changes. This will also hinder new oil attempting to drain down. As oil accumulates in the rocker boxes, the breather system can become overwhelmed and is defeated in its quest to keep oil spilling out onto the side of the motorcycle.

There are other reasons this oil build-up can occur, many of them fixable, but some are inexplicable: One Twin Cam will vent oil while a seemingly identical one will not. I can only think that once addressing any internal oil sealing, checking oil pump fitment, and eliminating rider style as possible causes, it must have to do with varying production tolerances.

Many times this problem traces to riding habits with a conservative rider experiencing no ill effects but an aggressive high-rpm rider suffering from this oil carryover affliction. Still the problem should not occur as potential rider aggressiveness ought to factor into the prevention equation.

The S&S "Reed Valve" Solution

The S&S solution is a crankcase breather valve for the TC88/TC96 Alpha motors. There is not one available for a Twin Cam B models or Sportsters. There is no extra space in the

TC88B and TC96B motors because of the counterbalancer mechanism. Furthermore, there is no extra space to accommodate a reed valve of this type in Sportster motors.

The reed valve is a machined billet aluminum body containing four steel reed valves. It installs easily, especially if doing cam work or checking the oil pump. Well, I guess I should qualify the last statement. It is easy for a competent technician.

Two-stroke engines use reed valves extensively but for a different purpose: They perform the same functions as four-stroke intake and exhaust valves.

The reed valve designed for Harley's allow the escape of air from the crankcase into the timing chest but do not allow it to flow back easily. The air-transfer-cycle is broken, allowing oil to return to the timing chest. Designed to work on crankcase pressure changes or differentials, the reed valve is an upgrade replacement that more than complements the stock breather apparatus located inside each rocker box.

The reed valve's four steel reeds are normally in a closed position. When the pistons descend in their cylinder bores, the air in the crankcase below the pistons becomes increasingly compressed. The pressure created on the Twin Cam flows not through a breather gear like on the Evos and predecessor models but through spaces between ball and bearing seats in the massive pinion roller bearing, that supports the right flywheel pinion shaft. This bearing separates the timing chest from the crankcase cavity housing the flywheel assembly.

The Twin Cam four-reed valve is shaped like a donut. The Evo three-reed valve is cylindrical in shape. Of course, the reason for this shape is that the Evo reed valve fits into the long cylindrical breather gear hole that connects the crank compartment with the timing compartment on the Evolution engine.

The Twin Cam's approximately three-inch circular reed valve that is about three-quarters of an inch thick, sits on the pinion shaft behind the internal oil pump and in front of the pinion bearing separating the two compartments; the timing compartment from the bottom-end compartment.

This pressure build-up of displaced air from the descending pistons forces the four reeds to push open, thereby allowing the air and oil mist in the crankcase to flow and escape into the cam timing chest compartment. When the pistons change direction and ascend their respective cylinder bores, a negative pressure is created in the crankcase. This vacuum pulls the four reeds into their closed position, preventing air from entering the crankcase via the pinion bearing.

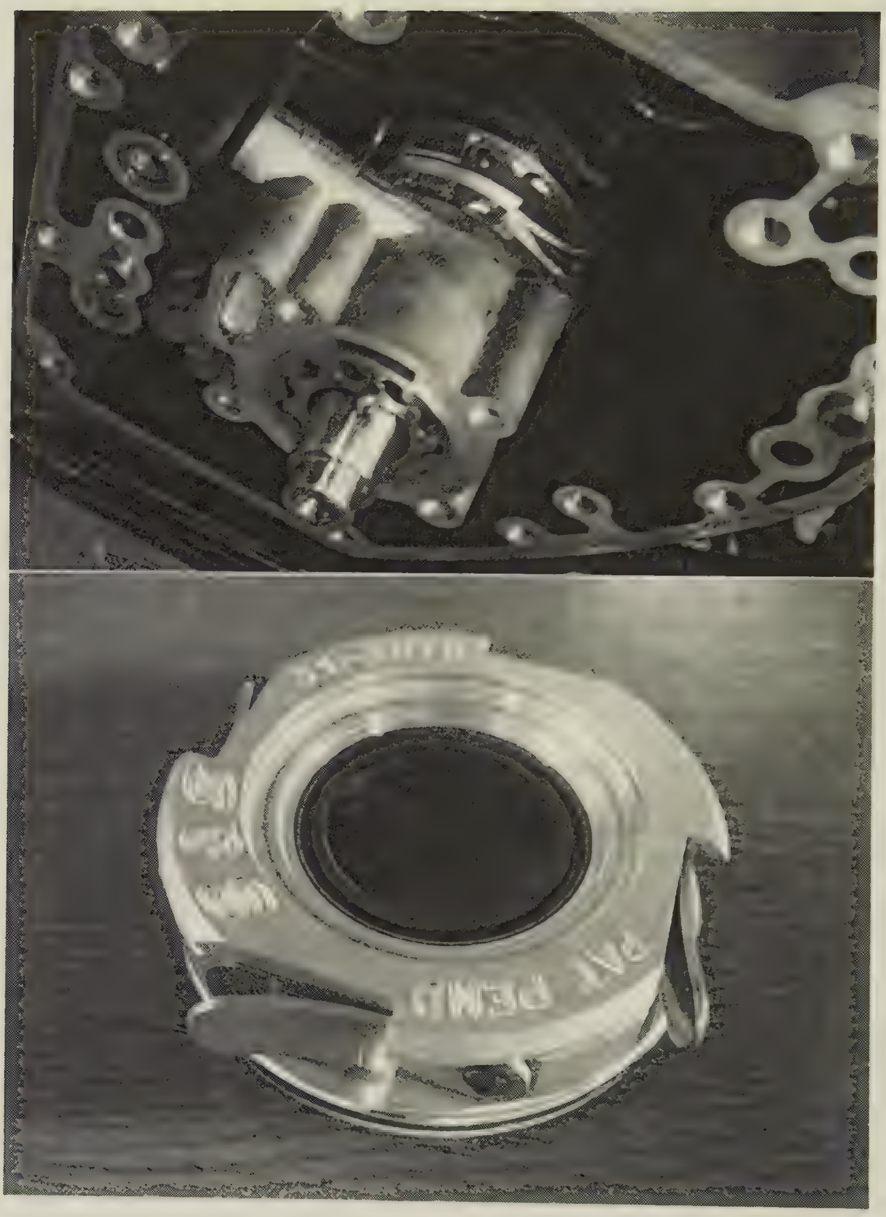
The Reed Valve Vacuum Improves Oil Return

Oil scavenging greatly improves by the effect of this slight vacuum, which reduces the potential for blowby. The vacuum's negative pressure is slight because lesser amounts of air will bleed by the two inside cam bearings and piston rings.

Air does not come down the top end oil-return holes into the crankcase like on the Evo since Twin Cam oil return diverts over to the timing compartment to allow for more efficient sump action on oil return to the oil tank.

While the Evo reed valve is a godsend in preventing oil blowby to the outside world, one can already discern that the Twin Cam reed valve is superior. This is because it has an extra reed but also the Twin Cam compartments are more airtight than on previous H-D engines.

I became aware of Internet chatter in 2008 about some users saying that they did not feel that the reed valve worked. I do not doubt the veracity of their opinions. However, after installing a multitude of them, I have not had a problem, as there has always been an improvement if not a cure. I feel that perhaps an O-ring seal in the timing chest is at fault leading to some complaints. Furthermore, sometimes loose manufacturing engine tolerances create a problem that a reed valve or other aftermarket fix cannot cope with.



The S&S Cycle, Inc. Reed Valve Locates in the Twin Cam Timing Chest between the Oil Pump and the Inner-Right-Engine Case

Pictured on top is a TC88A (Alpha) engine-timing compartment. The oil pump (26035-99, 26035-99A) mounts on and is driven by the pinion shaft. Behind the pump is an installed S&S Reed Valve (S&S 31-2070), which is a crankcase breather. The bottom picture shows the S&S Reed Valve for a 1999-2002 Twin Cam. There is a slightly different reed valve (S&S 31-2071) for 2003 and later Twin Cam Alpha engines. There is not one available for the Beta TC88B engine because the counterbalancer apparatus takes up any available space that a reed valve could occupy. S&S determined that displaced air from descending pistons was traveling up the return oil holes from the top end and preventing oil return. This causes a buildup of oil in the heads that sometimes overwhelms and gets past the breather apparatus escaping out of the head and down the outside of the bike. The breather is a machined three-quarters-inch-thick 3"-circular billet aluminum body containing four steel reed valves. One of the reeds is visible in the picture and looks like a metal flapper. The reed valve easily installs especially, if doing cam work or checking the oil pump. The reed valve's 4-reeds allow the escape of air from the crankcase into the timing chest but does not allow it back in. The four steel reeds are normally in a closed position. When the pistons descend in their cylinder bores, the air in the crankcase below the pistons becomes increasingly compressed. The pressure created flows through spaces between ball and bearing seats in the massive pinion ball bearing (24623-99, 24623B) that supports the right flywheel pinion shaft. The bearing separates the timing chest from the crankcase cavity housing the flywheel assembly. This pressure build-up of air displacement by the descending pistons forces the four reeds to push open, thereby allowing the air and oil mist in the crankcase to flow and escape into the cam-timing-chest compartment. When the pistons change direction and ascend their bores, they create a negative pressure in the crankcase. This vacuum pulls the four reeds into their closed position, preventing air from entering the crankcase via the pinion bearing. The cycle is broken allowing top end oil to return into the timing chest. Oil scavenging (return), greatly improves by the effect of this slight vacuum, which reduces the potential for blowby.

Real-Time Breathing Capabilities

Since the reed valves open and close precisely on demand, they automatically compensate for the mechanical lag time associated with the accelerating pressurized air mass forcefully exiting out of the crankcase. This is most significant at higher rpm where blowby potential is at its greatest when the time available to get the air out is the shortest. On-time breathing also compensates for faster moving pistons in much the same way in big-inch strokers. A piston must move farther up the bore and correspondingly farther down the bore in a stroked engine. The kick is that the pistons must do this in the same amount of time. Ergo, they move faster to accomplish this. Therefore, air displaces faster thereby increasing the potential once again for blowby. Big-bore kits also result in a bigger mass displacement of air.

The reed valve is a huge help in assisting the breather apparatus in separating oil from air and allowing the air to escape into the breather, only to draw back into the engine's combustion chamber to re-burn. The bottom line is that the moving gases caused by the pistons descending and ascending in their respective bores with the resultant pressure differentials open and close the four reed valves in tandem, allowing *for accurate and precise timing no matter what the changing piston speeds are.*

In fact as S&S says in its 2007 *Performance Guide*, "Our engineers were able to determine that the problem was caused by the continuous rise and fall of air pressure in the crankcase, cam chest, and rocker boxes. Large volumes of air moving in and out of the crankcase cause pressure changes as the pistons travel up and down. As a result of this air flow and the changes in pressure in the cam chest, air also flows in and out of the rocker boxes through the cylinder head oil drain passages. At sustained high speeds, the constant in-and-out flow of air in the rocker boxes interrupts the free flow of oil from the cylinder heads to the cam chest. "In fact, a small quantity of oil, pushed up and down by the pressure changes, is trapped in the drain passage, effectively blocking the passage so that no oil can drain out of the rocker boxes. "When enough oil has accumulated in the rocker boxes, it will start to blow out the breather passage to the air cleaner and ends up all over your bike, your passenger's new boots, and, in extreme cases, onto your rear tire. The reed valve allows air and oil mist to escape from the crankcase, but do not allow them to re-enter." [1]

S&S goes on to relate, "An engine with the S&S Breather Valve still has large swings in crankcase pressure as the pistons travel up and down, but that average crankcase pressure is reduced….The elimination of pressure changes and resulting air flow in the rocker boxes, allows the oil to drain smoothly down to the cam chest without interference from the turbulence. No more oil carryover." [2]

Another way to control blowby, oil carryover or oily venting, all three terms being synonymous for our purposes in this particular discussion, is to improve the Factory design for the breather apparatus in the rocker boxes.

The TP "ProVent" Solution

If upgrading the breather apparatus in order to better separate oil from venting gaseous air and/or to handle bigger volumes pushed up into the rocker boxes, the possibilities of controlling blowby improve. This concept applies both to Twin Cam 88/96/103/110 Alpha models and the thus-far-neglected B or Beta models as well as 1992 to 1999 Evolution Big Twins and Sportsters.

Improving the Breather Apparatus

Tom Pirone of TP Engineering (www.tpeng.com) has developed his ProVent rocker boxes with built-in breather components with a view to curing blowby on late Evolution's, late XL's, and, of course, Twin Cam engines. I think it obvious that one of the reasons that companies like TP and S&S are at the forefront of developing ways of controlling oil carryover is that a main part of their business is the manufacturing of big-inch V-twin engines. Big cubic inches have more swept volume inside the cylinders. This of course, leads to more displaced air as a result of those rapidly moving pistons that, in turn, leads to exacerbated blowby concerns.

A big advantage with the TP components is that their Twin Cam wafers fit on both A and B Twin Cam models from 1999 to the present. They also produce an Evolution set for 1992 to 1999 Big Twins that also fit 1991 to 2003 Sportsters. They bolt onto the above model years without any modifications.

At Heavy Duty, we routinely modify early 1984 to 1991 Big Twin heads to accommodate the later Evo breathing systems on stock or modified engines that have a serious oil carryover problem. While not perfect, the 1992 to 1999 breather apparatus is a dramatic improvement over what went on the 1984 to 1991 models.

Now it is possible to upgrade these earlier 1984 to 1991 engine heads to fit the T.P. ProVent rocker boxes for an even better blowby cure. This is exciting for us because we can now fix a problem that was very difficult, if not impossible, to fix previously.

The TP Engineering 2-piece rocker box is innovative in design and function. They are CNC-machined from billet aluminum. Rocker arm supports, also called stanchions, are integral with the rocker box for added strength, and not as a separate piece. The gorgeous mirror-finished boxes have a sleek appearance and complement any top end. The two-piece wedge design allows far easier access to internal parts for service and maintenance. Extra wall thickness reduces valve train noise.

TP has re-engineered the way oil separates from the venting air flowing out from the engine into the breather. Easier air movement separates the air from the oil more efficiently and nearly eliminates oil carryover into the air filter. Elimination of oil carry-over results without the use of rubber flapper valves found in Evo and Twin Cam rocker boxes.

Extensive R&D during the development of TP Engineering's line of Evo-style engines yielded ProVent technology; a simple, yet superior system, to separate the oil suspended in crankcase breather gasses. TP's system eliminates any oil from leaving the engine and entering the air cleaner without the use of moving or rubber parts. To accomplish this, TP utilizes a series of machined labyrinths to collect oil droplets as breather gasses traverse the passages at high speeds.

The easiest way to solve mechanical problems is to use the physical properties of matter; solid metals, liquids, or gasses to achieve goals, as opposed to having their physics work against you. Harness nature instead of fighting it.

ProVent boxes return the separated oil to the engine while clean air exits via the air cleaner. The stock rocker box's ability to remove oil from the breather gasses diminishes with both engine age and mileage as stock H-D rubber parts harden over time. This is one area where ProVent technology comes into play.

As the oily mist forces out of the crankcase, it blows into the cam chest, then up through the pushrod tubes and into the first chamber of the ProVent system via three entry holes that begin the process of extracting oil droplets from the vapor.

1. Each surface touched by the breather gasses collects suspended oil. The walls will be relatively cooler lessening the air's capability of carrying suspended oil.
2. The air collides with the walls of the chamber and makes a series of turns before climbing the last wall and flowing through the entry hole into the next chamber.
3. Rapid directional turns, again lessens the air's ability to suspend heavier molecules of oil because of inertia, momentum, and gravity.
4. In the second chamber, the breather gasses spin and collide with the walls. By the time the air climbs the final wall on its way out of the chamber, it is free of oil.
5. The cleansed air now enters the crossover channel in the rocker box cover, which routes the air out of the head and into the air cleaner.
6. In fact, TP claims this system cleans the air leaving the engine so well it allows for the elimination of the timed rotating breather valve in Evolution engines!Elimination of this gear also has the small benefit of reducing internal engine loss of frictional horsepower. The fewer parts the better. Crankcase pressure reduces by 2-psi.

I can be a nervous Nellie around engines. What I know to be theoretically true is sometimes difficult for me to put into practice as I succumb to the Harley tenet that more is better. I usually still use the breather gear even though I know I do not have to. My weakness will not allow me to eliminate it.

At Heavy Duty Cycles, we have found that the TP Engineering ProVent rocker wafers worked when we tested them on problematic engines. They are trick and beautiful.

I will continue my examination of blowby and the various methods that an inventive fellow named Tim Doherty has developed to combat Harley's marking their spot. I will also examine causes of this malady that may occur with a worker at the Factory having a bad day or your local wrench not installing components correctly. Many times, blowby is caused by using the wrong O-rings, incorrect installation, or failing to check for misaligned or warped parts inside the engine. Using an exotic fix for any of the above situations is attempting to correct a symptom instead of the cause. Of course, DSP dyno testing has proven that an exotic fix is sometimes necessary.

Pretty much gone are the days of actual oil leaks, which bedeviled the Factory for so long. Competing manufacturers and their loyal followings make derisive comments, such as "Harley's mark their spot". Harley riders who never admit to the outside world the deficiencies of their ride always turned adversity into accomplishment via sinful pride. Riders turned marking its spot into a bragging right whereby a Harley always took possession of its surroundings like a wolf staking its territory.

However, the wolf needed taming with the advent of emissions controls…leaks, exhaust emissions, blowby and noise…instituted by the Environmental Protection Agency, that began enforcement of the regulations in earnest in the mid-seventies. Up until this point, Harley's marked their spot relentlessly; expelling noxious pollutants from their exhaust; puked oil on the ground from its venting system, and emitted oilified carryover mists from the engine. The beast rattled, coughed, chugged, making far too much noise from exhausts, ill-fitted meshing gears, grating chains, and the noises not known outside of engineering circles like changing manifold air pressures.

The Flathead 80: a Study in Pollution

Around 1970, one of my first bikes was a 1938 80c.i Flathead. It was already an antique but a beauty for its day.

Adjustable Exhaust Baffling; Loud and Louder

The muffler that leaked noxious fumes at every junction had a lever that operated a baffle plate inside the muffler to quiet down the noise when entering urban areas. Once on rural roads the same lever allowed the exhaust to turn into a drag pipe with no muffling whatsoever. It was just plain loud no matter the lever position.

The Gear Backlash Heyday

Cam timing gears, of which, there were many, including the four separate cams driven by their four gears with all the others including the circuit drive, oil pump gears, generator and idler gears made unbelievable noise as gear backlash had a heyday. There was no thought to fuller contact carefully fitted gear interaction in those days. Furthermore, the encased front grating primary chain operated in an echo chamber facilitated by the tin primary covers.

Total Loss Oil System

Oil feed to the primary chain was a total-loss oiling system. Oil fed to the chain, dripped off via gravity and ran down to the lowest point of the primary to drip out onto the ground via a hole.

The engine oiling system was too much! While riding, or should I say bouncing along, on its rigid-frame chassis and Springer front end, if the engine started making noise from oil starvation, there was a push knob that the rider vigorously pumped to feed oil into the engine. If the engine started smoking white and blue smoke from too much oil building up, there was a lever to open a trapdoor at the bottom of the engine casings to let the oil fall out onto the roadway. America's dusty back roads were served well by the old girl marking her spot everywhere she went. No wonder the pollution cops went ballistic.

Even today's Twin Cam, the tightest and quietest of all Harley's with the exception of the next generation V-Rod, occasionally violates the dictates of the EPA.

Does the U.S. Gov't Cut H-D a Lot of Slack?

I think the American-made Harley-Davidson gets cut a lot of slack that foreign competitors do not get.

Prototype Twin Cams that I had the honor of observing in 1998 under secrecy agreements with the Factory indeed had very little engine noise, much quieter than the predecessor Evos did. However, production models that we ride have the whole spectrum of noise emanating from the engine. The ones I listen to daily are seldom as quiet as the prototypes I listened to and some are noisier than the Evos they replaced.

My opinion is that manufacturing tolerances cannot match those of hand-built prototypes. However, I could ask the question if foreign-made brand motorcycles are allowed the same latitude?

Oil leaks have pretty much been tamed since the excellent machining of mating parts combining with truly good gasketry, impervious O-rings in machined seats and improved seals thwart this. The main problem today is the occasional inability to completely separate venting air from impregnating oil that becomes an oilified mist.

TP Engineering's ProVent Rocker Box

Pictured is the TP Engineering ProVent bottom rocker box wafer for the front head. Opposite the FRONT stamping are two adjacent smaller round holes for the pushrod tunnels and pushrods. The two oblong holes, top left and lower left sit over and house the exhaust (top), and the intake valve springs (lower), and their respective valves. Blowby, also known as oil carryover is a venting problem. The first step is always to ensure that all internal oil passage-sealing O-rings are the correct ones and installed properly. Many Twin Cam O-rings look similar but are not identical. Warped mating parts will also make it impossible for an O-ring to seal fully. Internally leaking oil from improper O-ring sealed oil passages may overwhelm the stock breather system. The ProVent rocker boxes, front head and rear, stop any oil from leaving the engine and entering the air cleaner without the use of moving or rubber parts. TP utilizes a series of machined labyrinths (lower middle) to collect oil droplets as breather gasses traverse the passages at high speeds. The stock H-D rocker box's ability to remove oil from the breather gasses diminishes with both engine age and mileage as stock H-D rubber and foam parts harden over time. Some oil mixes with air, forming a gaseous mixture. Descending pistons force this gaseous air out of the crankcase and into the cam chest, and then up through the pushrod tubes and into the first chamber of the ProVent system via three entry holes that begin the process of extracting oil droplets from the vapor. Each surface touched by the breather gasses collects suspended oil. The walls will be relatively cooler, lessening the air's capability of carrying suspended oil. The air, colliding with the walls of the chamber, is forced to make a series of turns before climbing the last wall and flowing through the entry hole into the next chamber. Rapid directional turns again lessen the air's ability to suspend heavier molecules like oil because of inertia, momentum, and gravity. In the second chamber, the breather gasses spin and collide with its walls, and by the time the air climbs the final wall on its way out of the chamber, it is free of oil and ready to enter the crossover channel in the rocker box cover, which routes the air out of the head and into the air cleaner for re-ingestion back into the combustion chambers.

The Twin Cam 3-Stage Venting System

Again, the best venting system designed by the Factory to date is found on the Twin Cam, but sometimes it proves inadequate when riding at sustained high rpm and/or when increasing engine displacement from the stock Twin Cam.

- The breathing process has the seemingly easy but difficult task of separating oil molecules from the venting air.
- The second phase involves feeding these gases into the air breather before entering the EFI or carburetor throats.
- The slight vacuum created by the descending pistons on the intake stroke when the intake valves are open draws these expelled vented gases back into the combustion chambers for re-burning, thereby further decreasing harmful emissions. The breather system relieves pressure from the crankcase caused by ascending and descending pistons. The pressurized displacing air forces up into the rocker box area with the descending pistons on each intake stroke and power stroke. The air rushes under the rocker arm support plate and into an opening leading to the breather baffle compartment. There is one assembly in each rocker box. The obvious first advantage is that gravity will assist in separating the heavier oil from the gases, but the process needs more help than that.

The Foam Oil Scrubber

There is a three-stage system for venting the air back into the combustion chamber to burn off any oil residue and prevent all but a minimum of bad emissions from escaping. The open cell foam (63815-99), which is an oil filter-gauze element, scrubs oil from the oilified air vapor. Shaped like a 1"-long barrel, it is very porous. The foam easily allows air travel through it. This filter did not exist in the 19992 to 1999 Evolution system.

Breather Oil Drainage

The separated oil flows back through two small return holes in the rocker arm support plate to return to the timing chest; that is, unless there is too much volume to deal with!

I have already described the process to enlarge this drain hole, one in each head, to .103" or even .110" on problematic engines to allow more oil to bleed off and return to the timing case.

The Umbrella Valve

The cleansed air then feeds through an umbrella-flapper valve (26858-99), which rises to let the air through. The displaced upcoming air forces the valve open. The valve is a rubber, umbrella-shaped, one-way valve that lets air out of the engine but will not allow it back in.

Once the piston begins to ascend, pressure drops as air in the breather compartment reverses direction. The flaps of the umbrella valve drop down, thereby sealing the vent hole, which blocks this processed air from any return option. A similar umbrella valve (26856-89) also exists in the Evolution 1992 to 1999 engine but either valve, if overwhelmed will let the oil out along with the air.

Strenuous Air Passages Separate Oil

The air then follows a strenuous path allowing the gases to escape but retarding any leftover oil from doing so. Gases find this channel easy to follow, but heavier molecular oil does not.

Now, let's examine causes of this oil carryover malady that may not need innovative fixes developed by the likes of Doherty, S&S, and TP that can occur with a worker at the Factory having a bad day or your local wrench not installing components correctly.

Repair the Cause not a Symptom

Using the wrong sealing O-rings, improper installation, or neglecting to check for misaligned or warped parts inside the engine often causes blowby. Using an exotic solution for the above situations is attempting to correct a symptom instead of the cause. It may partially fix or even totally fix the symptom, but why layer the situation?

Of course, the DSP dyno testing by S&S has proven that an exotic fix is necessary if displaced air by the downward pistons interferes with oil return from the heads, thereby causing a build-up of oil that overwhelms the breather system.

The first areas we check at Heavy Duty Cycles when we encounter blowby is that all the stock components that have an ability to cause this situation have correct fitment, are not damaged, or missing. Yes, we have found missing sealing O-rings not installed at all, both apparently right from the Factory assembly line and by neglectful mechanics in dealer and aftermarket service shops!

It is of paramount importance that the O-rings that act as seals between the many component parts of the oiling system are not leaking. If various O-rings are not able to do their job, particularly on the oil-feed side as intended by Harley, then oil will seep, bleed or gush past the juncture and into the timing chest compartment. This is tantamount to internal bleeding, not only causing a lowering of oil pressure but a situation the venting system was not designed for and therefore not prepared to deal with.

The workshop manual also addresses these issues and cautions against distorted, wrong, pinched, or missing O-rings. It also warns that some different O-rings may indeed look the same and used inadvertently. Oil leaking past a worn or forgotten seal can overwhelm the return side of the oil pump as too much oil will build up in the cam chest compartment. The return side of the pump cannot remove this excess oil fast enough because it is not designed for this much quantity.

Some of the buildup of oil will start to vaporize. Engine parts movement creates the vapor-rich mixture of oil in the air. Drawn up the pushrod tunnels into the heads, this mixture places a burden on the breather system. The breather is not able to handle this quantity and oil is forced by it and into the outside world.

In addition, the oil return holes in the heads and cylinders must endure transiting upward-traveling oil vapor, which can disrupt oil return, exacerbating the problem. The result is that there will be too much oil inside the rocker boxes, some of which will blowby the breather apparatus.

In 2011, H-D redesigns the breather apparatus. The design looks less expensive. Gasketing now assists in oil separation. More on this in Chapter VI: *2011 Model Changes.*

Sometimes Defective or Missing Parts Cause Blowby

Do not always think the blowby is a design problem rather than error. Alternatively, is it simply a warped or wrongly installed part causing excess oil to bleed off into the timing chest?

People and that certainly include mechanics; generally forget to check the obvious. This is because it is so simple. A mentality exists that there must be a more complicated cause to the perplexing problem at hand.

The most obvious and easy thing to check in this case is to ensure that the oil pan/oil tank is not overfilled. The oil reservoir must have air at the top to allow venting.

Blocked Oil and Vent Lines

No air equals no venting. No venting means that excess oil will be forced out somewhere. The second thing to check with a suspect venting problem is a clogged oil return. The manual wisely instructs to check the above, and I agree, always check.

Examine Internal Oil-feed Junctions

1. Next inspect all oil-feed junctions that are sealed with O-rings. The O-rings used extensively inside the TC88 engines must be the correct ones.
2. Then ensure the correct installation of the O-rings.
3. Next, guarantee the O-rings are capable of sealing.
4. After that check mating parts for defects or warpage that will prevent the O-rings from effectively sealing.
5. However, who is to say, as I have serviced a bike with a crucial O-ring missing that did not suffer blowby. I can only surmise that the machining on both mating parts must have been superb, the bike had not been bored to 1550cc, and the rider rode very conservatively.

In one blowby-plagued machine that we serviced at my shop, we discovered that the oil pump surface that mates against the cam support plate was mal-machined right from the get-go at the Factory; the surface was irregular as if there were a machining problem. Replacement of the support plate solved the blowby problem.

Warped Cam Support Plate

Specifications dictate replacement of the cam support plate if warped. The maximum warpage allowed is .010" (ten-thousandths of an inch). Check your manual for your year support plate's maximum warpage specification. If warped, the support plate throws out other specifications. Warpage may make it impossible for an O-ring to seal.

Pinion Shaft Runout

Also, replace the support plate if the pinion shaft bushing fit exceeds .0008" to .001" (eight, ten-thousandths of an inch to one-thousandths of an inch).

This is a touchy subject because I have found that sometimes the pinion shaft comes right from the Factory with more than the .001" runout I prefer. I have seen a disturbing number with .003" to .004" runout and there is the odd one with more. I have also seen many with as little as .0005" (one half of one-thousandths-of-an-inch) runout, which is outstanding. If I had to give an educated guess, I would say that runout on early Twin Cams is likely to be less than later ones. By 2008, H-D has increased allowable runout specifications exponentially. I very much disagree with relaxing these specifications and spend a lot of time discussing this in detail in Volume II: *Performancing the Twin Cam.*

While I speak all the time of problematic cases of excess runout, in the big scheme of things, I would have to qualify with my experience that the early Twin Cam flywheels are the most accurately trued ones of all that have gone before since 1903.

The riding public is no longer tolerant of vibration, which out-of-true flywheel assemblies certainly create. However, vibration suppresses in all Twin Cams via counterbalancing the Beta engines and rubber mounting the Alpha ones.

At Heavy Duty Cycles we measure the runout that is at or near the end of the pinion shaft where maximum exaggeration occurs. Harley-Davidson recommends checking runout at the pinion-bearing surface near the flywheel. A smaller variance of flywheel trueness will become exponentially greater at the end of the shaft.

The pinion shaft bushing is located in the cam support plate. The pinion shaft extends through this bushing just enough for the primary timing chain's cam drive sprocket to fit on. Therefore, bushing fitment further distorts if runout on the pinion shaft is more than three-thousandths of an inch.

The pinion shafts rotation is very powerful. The shaft will hog out the bushing way beyond the prescribed tolerance. A parts-replacer technician will replace the cam support plate as the manual instructs. A repair-oriented mechanic will replace and ream out a new bushing, which is much less expensive. Either way, this repair will hardly fix the cause of the problem. It will only temporarily fix the symptom.

The solution to the problem then becomes putting a completely new bottom-end crank into the engine. If the engine is under warranty, this is always the way to go. If the customer has to foot the bill, the situation changes dramatically because many cannot afford such an expensive repair. The thinking mechanic will learn to replace the bottom end when the bushing fitment will begin to affect the delivery of crucial bottom end oiling. In this case, we may not want to replace the crank if bushing fitment is say, under three-thousandths of an inch, which is triple the prescribed specification.

In Volume II: *Performancing the Twin Cam,* I describe how to re-true Twin Cam flywheels. I also explain how I do a welding procedure to ensure the flywheels remain true.

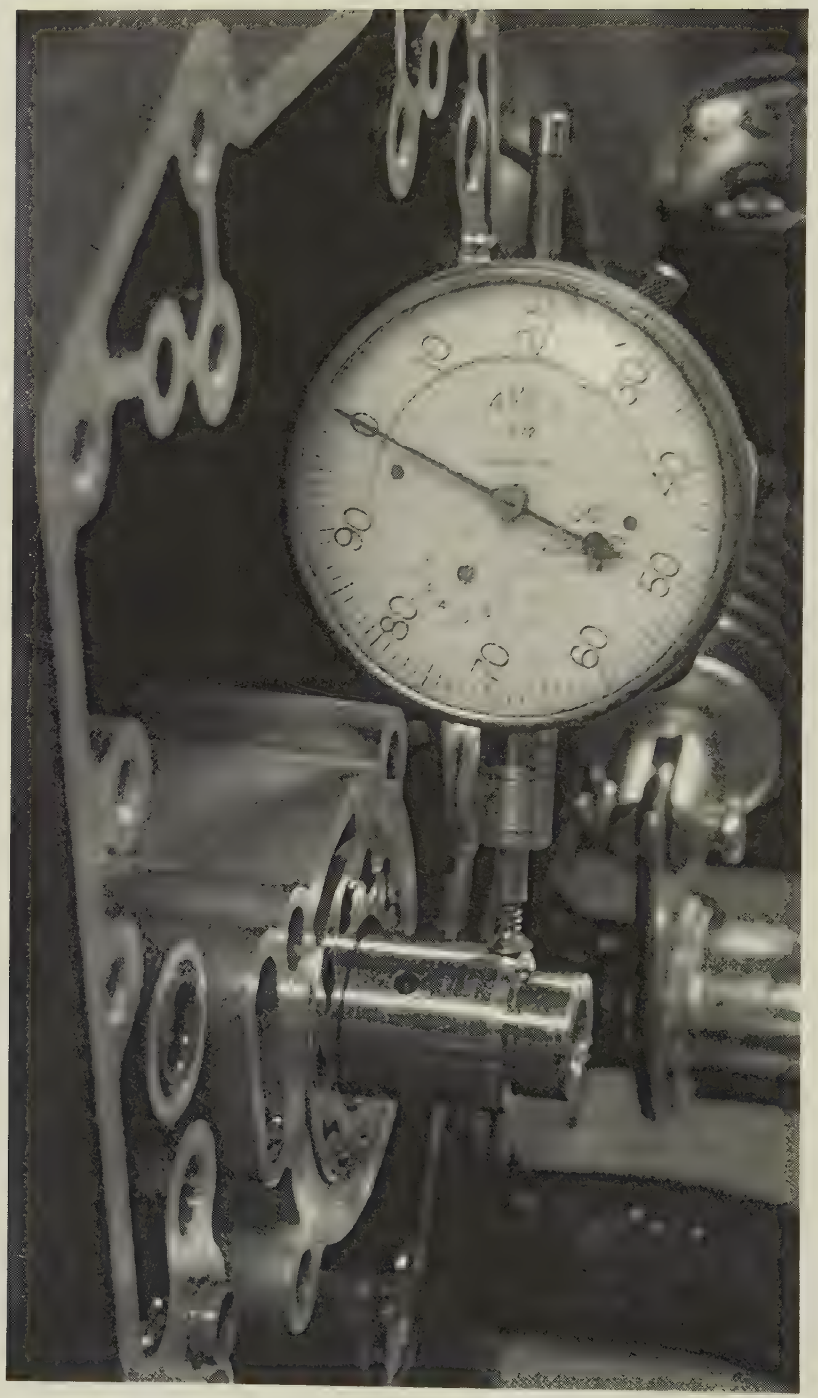
Oil Feed O-Ring Junctures

Examination of all junctures is necessary and O-ring installation performed correctly.

Some crucial areas are:

1. The side of the oil pump that fits against the cam support plate is the feed side. This O-ring (H-D 11286) seals the pump against the support plate.
2. O-ring HD-11301 seals the cam support plate to the engine casing.
3. On TC88B engines, there is an extra feed for the counterbalancers. It also takes an HD-11301 O-ring. If this O-ring is missing, crimped etc., oil will bleed down into the timing chest. The cam support plate from 2000 on has this feedhole.
4. When installing an HD-11301 O-ring on a TC88Alpha model without counterbalancers there is a screw and washer to block this hole. If not blocked, oil will feed right into the timing chest unobstructed with resultant oil blowby, plus a loss in oil pressure.
5. An oil pressure drop at highway speeds will be noticeable with any of the above seal leakage examples. Always check oil pressure at highway speeds to determine if leakage may be occurring, which will cause oil build-up increasing the potential for blowby.
6. Lifter noise is a sure sign that this may be happening.

Blowby does not happen immediately because the build-up and resultant actions take some time. This is why blowby sometimes does not occur until after sustained high-speed riding.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Measuring Twin Cam Pinion Shaft Runout

Pictured is a dial indicator, which is a rotational measuring micrometer that has been positioned via a magnetic stand (not shown), to ride on the end of the engine crank's pinion shaft. Rotate the engine slowly by hand, thereby rotating the shaft. Pinion shaft rotating trueness should not be more than two-thousandths of an inch (.002"). At Heavy Duty, we are not satisfied with this and always true flywheels to .001" runout or less. Whenever the engine shafts are exposed, we check shaft runout while working on an engine. Much early Twin Cam pinion shaft runout is less than .001" with lots at .0005". These engines will vibrate less and last longer before requiring a rebuild. However, some are out of whack, and this will affect cam support plate fixed-pinion bushing fitment with the rotating pinion shaft. This in turn will ultimately affect oil pressure to the heart of the engine, the bottom-end crank. Replacement of the flywheels if at .003" runout is technically necessary although incredibly in 2007 H-D increases the tolerance further. However, crank replacement is not practical for most pocketbooks. If the shaft is beyond this tolerance, particularly if runout approaches or goes beyond .004", removal of the engine from the chassis is required to split the engine cases to remove the flywheel crank assembly. A pressed-in crank pin connects the two flywheel halves. The flywheel halves re-true to each other so that sprocket shaft and pinion shaft runout is .001" or less. Modern technicians simply install a new crank. No one teaches them how to re-true a flywheel crank assembly. Older engine mechanics are very proficient at the less-expensive truing process. We true Twin Cam cranks at Heavy Duty and spot-weld the crankpin to the flywheels afterwards. Please see Volume II: *Performancing the Twin Cam*, Chapter III: *H-D 110 Cubic Inch CVO* and Chapter V: *Twin Cam Vibration* for detailed step-by-step information on this procedure.

Oil Pump Alignment Methodologies

Oil pump alignment is frequently out because of improper installation. This can result in premature wear as well as an improper seal against the cam support plate and/or the crankcase.

1. On the cam support feed side, this allows oil seepage into the timing chest and possible resultant oil carryover.
2. On the crankcase return side, an improper seal might result in less than ideal oil return from the crankcase flywheel compartment.
3. Firstly, lube the O-rings that fit between the pump and mating parts, the crankcase and the cam support plate, with a thin film of clean 20W50 engine oil.
4. Assemble the oil pump loosely against the backside (engine side), cam support plate and slide over the pinion shaft.
5. Install the cam support plate to the crankcase flange according to the manual with the six 1"-long screws.
6. Torque the screws to 90-120 in-lbs (10.2-13.6 Nm).
7. Do not make the mistake of doing this in ft-lbs, since all the screws will strip the threads in the softer aluminum-crankcase flange.

8. Torque the screws down in the following sequence: bottom left; right-side upper; top left; right-side lower, left side, and top right.
9. Alternately, snug and tighten a few times until reaching the specified torque.
10. At Heavy Duty, until we correctly align and torque the oil pump to its specified values, we do not tighten the cam support plate to full torque values.
11. Pay attention to Allen head socket screw length since both the hydraulic lifter covers and the cam support plate utilize the same ¼"-20 threads per inch screws. The lifter cover also uses Allen head socket screws that are ¼"-20. However, the difference is that the lifter cover uses screws (H-D 4741A) are 1¼" long, while the cam support plate uses 1"-screws (H-D 4740A).
12. In 1999, there were no specialized H-D tools for oil pump alignment even though Evolution mechanics had one right under their nose.

We would install the four oil pump bolts loosely to keep the oil pump semi-aligned.

1. Slowly rotate the engine to align the pump. It seeks the most comfortable spot.
2. Gently snug the bolts.
3. Rotate the engine again.
4. A sensitive mechanic…no daydreaming allowed…will be able to feel inappropriate drag if the oil pump is not aligning correctly.
5. Now torque the oil pump bolts to indicated values (90-120 in-lbs (10.2-13.6Nm) and in the proper sequence dictated by the manual. This alternative snug-and-tighten methodology is utilized everywhere in mechanics where there are a number of fasteners holding down warp sensitive parts.
6. Cast into the cam support plate are the four tightening-sequential numbers; one is bottom left; two is top right; three is bottom right, and four is top left.

Then, someone made a discovery that the Evolution 1984 to 2000 Big Twin hydraulic lifter guide, also known as a tappet guide block alignment tool (HD33443), would also align the Twin Cam oil pump if an extra tool were purchased. There is no excuse, unless on the side of the road, for not using these two alignment tools. They are 1 ⅝" long, with one end a ¼"-20-threaded portion to screw in place of the oil pump hold down screw while the other end has a hex head to accommodate a five-sixteenths inch wrench or a five-sixteenths hex head socket. The middle portion has a graduated smooth taper that increases from the quarter inch to five-sixteenths inch.

Using two of these tools diametrically opposed to each other on either side of the oil pump centers the oil pump to the holes in the cam support plate perfectly, thereby aligning the oil pump.

1. Leave the two oil pump screws loosely in the number three (bottom-right), and number four (top-left) positions.
2. Remove number one (bottom left), and number two (top right) screws and insert the two alignment studs in their place.
3. While slowly rotating the engine alternately snug the alignment tools until tightened to 40 in-lbs to 45 in-lbs, which is a little less than half the final specified torque.
4. Then alternately snug the bolts in hole number three (bottom right) and number four (top left) positions until tightened to the same intermediate 40 in-lbs to 45 in-lbs.
5. Install the bolts, alternately snug, and tighten, again to 40 in-lbs to 45 in-lbs after removing the alignment pins.
6. Finally, tighten all four screws (bolts) alternately in the sequence described above to the final specified torque values.

Quality Control

We have found bikes, some from the Factory, with only two bolts torqued and the other two left loose and in various other combinations. I have been taught by Harley managers and engineers the very impressive and sophisticated quality controls utilized by the Factory; watched them being performed and seen the computer tell the technicians what quality problems to concentrate on based on previously caught data.

However, at anytime an employee may not care or be having a bad day. Tooling can also break on the robots causing similar predicaments. Unfortunately, the problem must be repeated sometimes many times before the system catches mistakes.

It is not necessary to remove the cam support plate if oil pump realignment is the only goal.

1. Loosen the four screws.
2. Remove number one and number two screws.
3. Replace these with the alignment pins.
4. Snug the pins to the intermediate torque, etc. with the above procedure and specifications and perform the torquing sequence.

However, if it were your bike, wouldn't you want the O-rings checked and replaced just out of principle since you are in there anyway?

At Heavy Duty, we rotate the engine with spark plugs removed to relieve any compression and with the transmission in fifth gear. We already have the bike sitting on a stand so that the mechanic can use both hands with the cam support plate and oil pump while seated, pushing the rear tire with his left foot to rotate the powertrain and therefore the engine. The whole procedure is performed comfortably as the right foot balances the body.

The Doherty "Myst" Free Fix

Tim Doherty at Doherty Machine has been developing various effective systems to combat oil carryover for many years now. He has reinvented the breather apparatus that fits in each Twin Cam head so that it works as it should and not be overwhelmed. His only stipulation is that the potential O-ring problems and possible oil pump misalignment listed above are checked and addressed, if need be, before using his product. Doherty calls his breather apparatus the Mystfree.

Tim Doherty thinks, and I agree, "The two biggest reasons for excessive oil blowby are incorrect alignment of the oil pump and poor oil separation in the cylinder heads' breather valves. Inexperienced technicians who are installing camshafts and do not follow the correct oil pump alignment procedure when they reinstall the cam plate are responsible for most of the oil pump alignment problems. The poor oil separation up in the cylinder heads is caused by the stock breather valves being overwhelmed by the volume of oily/air mist that gets up to the valves during a really hard ride." [3]

We have now tested and used for many years now, the superbly made and aesthetically pleasing Doherty Machine products at Heavy Duty Cycles. They work very well.

First, remove the stock H-D breather apparatus from inside the rocker box on each head. Replace with the Doherty breather, again one for each head.

1. Disruption of the oilified mist is essential in a variety of ways to allow physical principles like gravity to do the oil separation work.
2. The first disruption of the air/oil mist occurs as it engages the copper base gasket of the Mystfree breather device.

3. The oilified gaseous mix is swirled around the lower cylindrical base, which begins the separation of air and oil.
4. The stock factory units have a single chamber separator that is fitted with a gauze element, whereas the Mystfree breather valves use a two-chamber oil separator.
5. A cylinder is cast into the center of the rocker arm support that protrudes into it from the bottom of the Mystfree valve body augmenting the first of the two chambers.
6. The first cylinder has three openings spaced around its edge that reverses the pressurized air/oil mist that is inside to change direction several times, as it pushes towards the exit in the breather valve.
7. Most of the oil is separated in the first-stage lower chamber but as with the Factory H-D design, one chamber is good for problem-free Twin Cams but is not enough for troublesome bikes.
8. As the oil mist, moves up against the walls of the lower chamber, most of the oil from the oilified mist separates and returns via the stock bleed holes in the bottom of the chamber.
9. This procedure involves some principles of physics that we all ignored in school but need now is best explained with an analogy. The Doherty Machine Mystfree oil separation is analogous to how grass collects dew as air moves through the foliage. The grass works as a separator of dew from the air.
10. When the pressurized air passes through the six holes in the Mystfree valve, it hits the bottom of the neoprene umbrella valve, causing it to rise up, thereby opening into the second chamber. Any remaining oil that has not been separated passes from the lower portion of the unit through the umbrella valve.
11. The Doherty umbrella valve differs from the H-D one-way valve as the umbrella does not lock into its seat. Instead, it floats on its stem, opens and closes much like a piston. The floating Doherty neoprene umbrella has a smaller diameter than that of the stock Twin Cam fixed umbrella valve.
12. Bernoulli's Principle comes into effect. A higher vacuum develops in the second separation chamber that helps to pull any oil back into the cylinder head's rocker box.
13. This is analogous to a river that flows faster in a narrows and slows down as the banks widen. The same volume of water must move through the smaller space in the same amount of time because of the unrelenting pressure coming from behind. The only way it can do this is to speed up. The opposite occurs as the riverbank widens.
14. This oil now drains off through the $^1/_{16}$"-slots incorporated into the top of the Mystfree body.
15. No oil residue is supposed to reach the raised air outlet located on the top front portion of the Mystfree apparatus. Two things occur with any oil that is present in the top cavity of the Mystfree.

Looking at a Mystfree, the reader will notice that there is a washer with a snap ring with a .750" (¾"), inner diameter hole in it. The purpose of incorporating this is to continue the air and oil separation process of any liquid that gets past the umbrella valve.

1. Creation of a vacuum under the washer sucks any oil back through the .060 vacuum portholes on the bottom of the Mystfree unit.
    a) This recovered oil returns to the rocker box cavity and flows downwards into the oil return hole from the head, through the cylinder and engine casing into the timing chest.

Secondly, there is a raised stanchion in the front of the Mystfree body. If there is any liquid still present, it has to overcome that raised portion to exit the breather system.

Mystfree Installation

Tim Doherty also includes a .089 drill with the Mystfree and recommends that installers open the two stock drain holes in the rocker arm supports, which are currently .060" to aid in draining the oil out of the rocker support cavity quicker. He has observed significant success in doing this and has added a supplement to the instructions. The rocker arm support hole is different from the return oil passage that I discussed earlier. When installing the Doherty Mystfree oil separators:

Raise the gas tank without removing it to allow access to the rear rocker box.

1. It is then a simple procedure to remove the six hold-down bolts on front and rear rocker wafers.
2. The Mystfree installs in the former placement of the stock breather apparatus after their removal.
3. Installation time may be as little as one hour, but two hours is more realistic.

The Power Vent

Two other nifty items that Tim sells are the Power Vent crankcase ventilation systems.

One is a cylindrically shaped single unit. I would use this for 1991 and earlier Evos, Shovels and Pans, as well as earlier Sportsters that vent out of the lower portion of the engine crankcases. It will also work on top-venting engines like 1992 to 2007 Big Twins and 1991-to-present XL's. If using it for this purpose, also purchase an aftermarket kit for mounting the Power Vent. Both vent holes join to a single line that connects to the single crank vent. This crank vent also comes with a nipple for insertion into the end of the vent body for attaching a supplied clear hose along with a filter. The filter is a separate purchase.

Tim Doherty has also developed gorgeous crankcase vents that fit on both the vent holes, one coming out of each head for the top venting engines. These can also be attached to a filter(s) via supplied nipples. There are kits developed for 1991 and later XL's, 1992 to 1999 Evolutions, and, of course, a kit for the Twin Cams. They are machined billet and polished to a lustrous shine.

Some aftermarket engines like S&S may come with both top venting heads and the lower crankcase vent. This makes it easier to control blowby because these engines are usually mega cubed. For these applications, use the cylindrical single crank vent for the bottom and the dual kit on the top head vents.

As Tim rightly and honestly says, "One of the most important reasons and benefits in the function of the Power Vent is that they significantly reduce oil carryover. If installed on an engine with minimal oil mist they have proven to reduce the mist to carryover to almost nothing. This occurs as a result in the decrease in crankcase pressure. However, I would like to make one point clear. Other manufacturers of similar products have advertised and claim these types of externally installed devices will *stop* oil misting. No external device will accomplish this "period." [4]

Well, I can relate to Tim's comments in a big way. My former shop, Heavy Duty Cycles, loses business sometimes because we give honest answers while a competitor may polish the truth, so to speak.

With a problem bike, the Mystfree works much better to solve blowby or carryover.

The Power Vent is a very air-sensitive, one-way valve, the same as the umbrella valve utilized in the Mystfree where almost virtually any air movement one way will open it and any air movement the opposite way will close it. The Doherty device allows the crankcase air to escape on the down stroke of the piston, but does not allow any air to enter the breather system on the upstroke of the pistons, hence decreasing crankcase pressure.

The Power Vent like the Mystfree differs from any other one-way valve on the market as the umbrella valve floats on its stem.

Decreased crankcase pressure will also assist in lessening oil carryover since there is less air to pick up oil and there will be less interference of displaced air preventing top end oil from returning down the oil return holes. The decrease in crankcase pressure allows a slight increase in power for two reasons: I quote Tim, "The pistons are not meeting as much resistance on the down stroke since there is less air stored in the crankcase. Testing the Evolutions typically would give us about 3 HP. The Twin Cams would always give us, one possibly two, measurable HP on a dyno. The second benefit would be better ring stabilization. On the compression stroke, the pistons are being pushed from the top due to pressure, but with significant air storage (i.e. pressure) they are also being slightly pushed from the bottom, which causes a ring flutter condition. Although the vents are only capable of working on a limited basis, their theory is really based on what has become increasingly popular in the automotive racing field, which is the use of mechanically driven vacuum pumps. The results in our experience have been dramatic. For example a 25 to 30 HP gain based on a 700 HP engine has been achieved." [5]

Therefore, the Power Vent will:

1. Give a small increase in horsepower.
2. Prevent modest amounts of oil carryover.
3. Decrease ring flutter inside the engine. This, in turn, allows the rings to do their compression and oil scraping functions more efficiently while adding to the longevity of the related engine components.

Superb aftermarket companies like Doherty Machine, TP Engineering, S&S Cycle, Inc. and others help the H-D rider combat the oil carryover that has plagued some Harley engines forever. The reputation and actuality of marking its spot is certainly being reduced through factory efforts and redesign, but it seems when one issue is resolved, another seems to pop out, necessitating the help of enthusiasts like Tim Doherty.

The 2007 Harley Oil Pump Scavenging Fix

I had anticipated that Harley-Davidson might introduce new measures in the 2007 model year to combat oil carryover also known as blowby or external venting. Little did anyone know that H-D in another stroke of marketing genius would increase engine size from 88 cubic inches to a 96-incher? This is achieved not by a bigger bore but increasing the piston stroke from 4.000" to 4.375" (4 ⅜"). As I have discussed, strokers create more swept volume, producing more power because more fuel and air is drawn into the cylinders and combustion chambers. The new 2007 Twin Cam has a total swept volume of 96c.i or in metric measurement 1584cc (cubic centimeters).

The bigger the engines get, the more likely it will suffer blowby. Therefore, it was only natural that H-D did something more to reduce the chances of blowby with its increased displacement 2007 Twin Cams. The Factory felt that if less oil remained in the engine waiting to sump back into the oil tank that the rushing displacing air would not be able to mix and pick excess oil up so easily. This is all about making the breather apparatus' job easier and less strained.

H-D has a redesigned and upgraded oil pump in the 2006 Dyna Glides and all 2007-to-present Twin Cams. Increased stroke means more heat so H-D did a good double whammy. Harley increased the 2007 oil pump feed to 10% more flow. This ensures better lubrication and cooling since one of oil's major functions is to remove heat.

On the return side, this new pump increases scavenging oil from the bottom end by a whopping 23%. Therefore, we have the potential here for some good results, both in cooling and in controlling a source of blowby, thereby preventing the new Harley's from marking their spot. Time will tell. As of 2011, I can report good improvement.

Softail Oil Tank can be Blowby Cause

Before looking for complicated causes and fixes to a problem check the easier and less expensive potential causes first. This may seem repetitive but the next two points are central to the issue

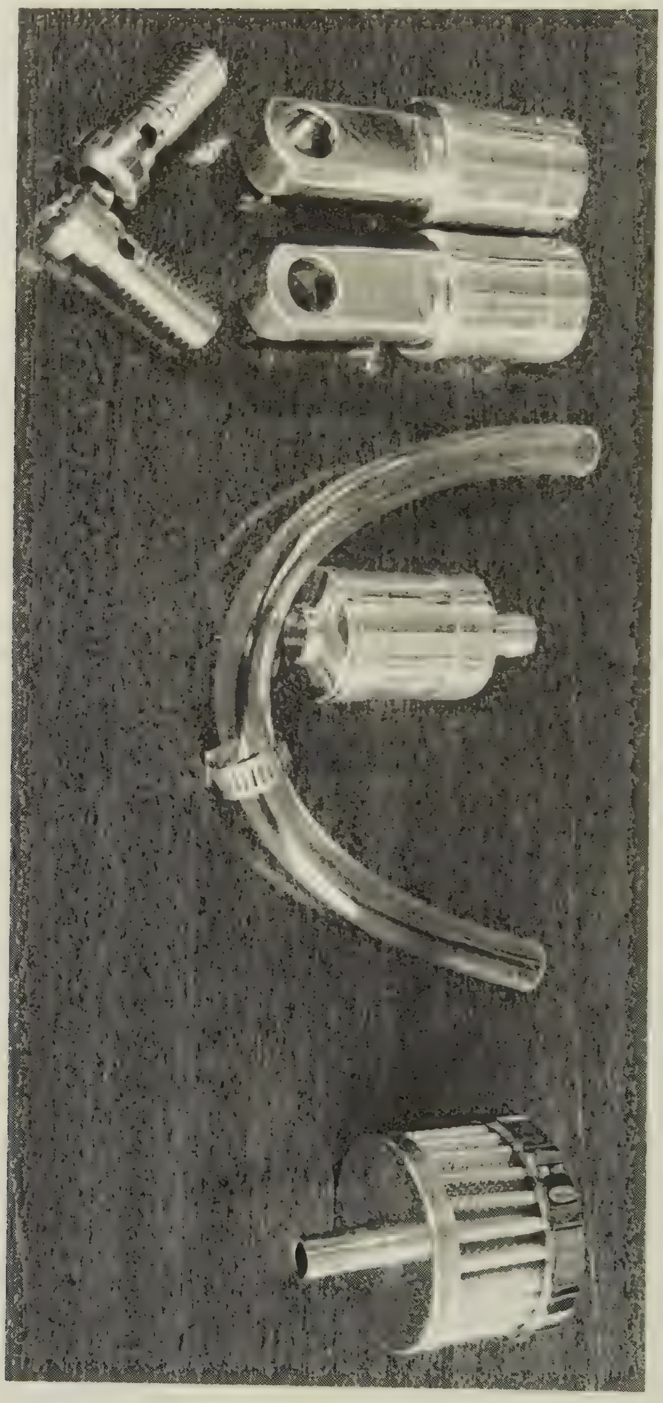
1. Always ask the complaining Harley owner about his or her riding style since this can be a leading cause of oil blowby. High speed riding for long periods increases internal air displacement overwhelming the breather system. Next, ask if any performance work has been done, particularly an increase in engine displacement from big bore kits TC88 to TC95 and TC96 to TC 103 or an increase in engine stroke (TC103 to TC110, 116, 124). A boost in displacement is an increase in the swept volume of the pistons. This increases the amount of air displacing inside the engine, which may overwhelm the breather system. Conservatively modifying riding style will assist in controlling blowby in either situation.
2. The various O-rings inside the timing compartment must be checked in order to ensure they are the right ones and are properly installed. Oil feed pressure in particular will leak past errant O-rings and eventually overwhelm the breather system with too much volume as well as negatively affecting crucial oil supply to moving parts.

This section only applies to 2008-to-present Softail FXCW and FXCWC oil tanks with the H-D 33528-08 return oil line and the H-D 33529-08 vent line that attaches to the reservoir bottom requiring internal standpipes that travel upwards above the oil tank oil level. It also has much application to Evolution Softail oil tanks since the return and vent lines attach to the bottom of the reservoir and also feed into internal standpipes. Harley Davidson, wisely moved the intersect points for the return and vent lines to the top of the reservoir on all Twin Cam Softail models beginning in 2000 and continuing to present except for the stylish FXCW and FXCWC motorcycles.

I kept dismissing the Softail oil tank internal standpipe construction as a primal cause of blowby out the breather but I constantly found references to this in my research. Now, I think the vent and return bottom mounting oil line Softail oil tanks must be checked for persistent blowby that does not seem to cure or diminish with other checks and fixes.

There are two standpipes also known as stand tubes inside these specific tanks. If there are no stand tubes in an oil tank like on the majority of Twin Cam Softail oil tanks, there would be only one fitting at the bottom of the tank, which will be the engine oil feed nipple. The oil feed only has a short standpipe to draw oil from above where sediment will settle. The oil feed will not cause blowby because there is always supposed to be oil in its short standpipe.

For the Softail tanks that have three nipples at the tank bottom; both the vent and the return will have a standpipe that is supposed to travel *above the tank's oil level at all times* whether the bike is leaning on the sidestand, a right or left curve on the highway or upright. This is another reason it is so important not to overfill the oil reservoir.



Doherty Machine Crank Vents

Pictured is the superbly machined billet, high quality polished Doherty Machine Powervent Crankcase Ventilation Systems. The top kit is for top-end engine breathing with kits developed for 1991 and later XL's, 1992 to 2000 Evolutions, and of course a kit for the Twin Cams 1999 to present. There is a crank vent for each head with a hollow breather bolt to both affix the crank vent and to allow air to channel out of each head into the crank vent. The middle kit is a Powervent, which is a cylindrical single crank vent for bottom end venting like that on pre-1991 Sportsters and pre-1992 Evolutions although it can be used on later models also. This single crank vent also comes with a nipple that inserts into the end of the vent body so that a supplied clear hose attaches along with a filter like the bottom item in the picture. No external vent will cure all oil carryover/ blowby but they are an easy fix to cure a mild condition or improve a bad situation. With an aggravating problem bike, the Doherty Mystfree, S&S Reed Valve, or the TP ProVent Rockers will work much better to solve blowby/oil carryover. The Powervent is a very air sensitive one-way valve with the same umbrella valve utilized in the Mystfree crank vents where almost virtually any air movement one way will open it or opposite air movement will close the vent. The Doherty device allows the crankcase air to escape on the down stroke of the piston, but does not allow any air to enter the breather system on the upstroke of the pistons. Hence, there is decreased crankcase pressure. Using these devices will also give a slight increase in horsepower and better throttle response because of less air resistance in the crank.

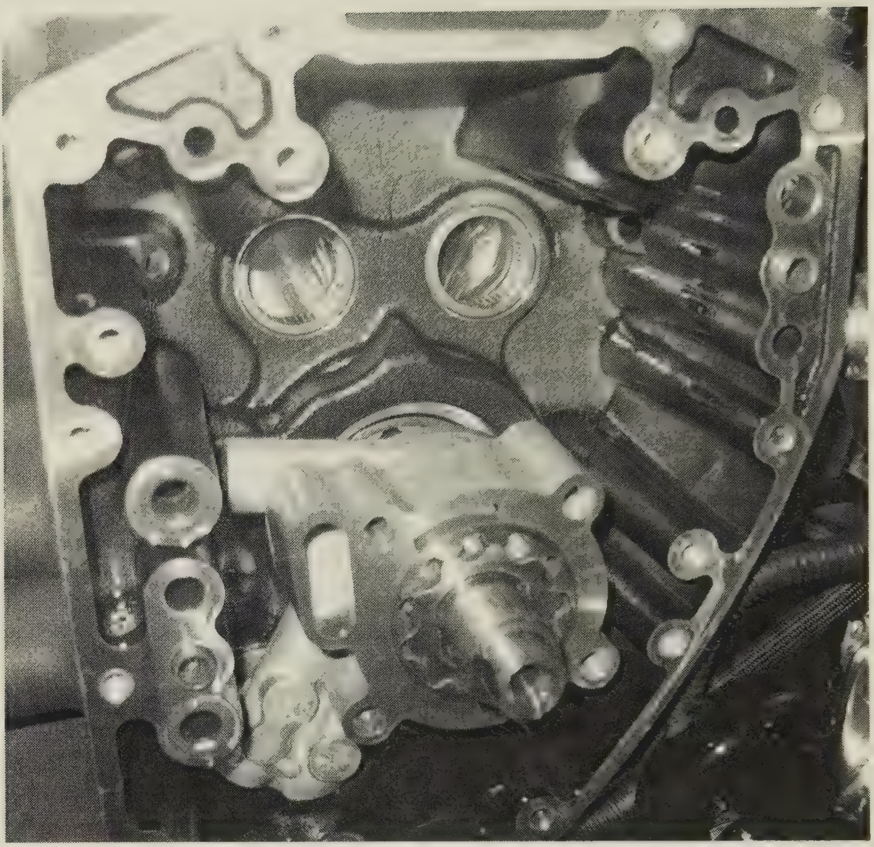
The types of internal oil tank-reservoir malfunction are:

1. What if there is a manufacturing defect and the vent standpipe sits below the oil level instead of above it? Well, we have a cause for oil blowby as oil will constantly drain into the vent and back into the engine overwhelming the breather-separation process. Furthermore, the engine's breathing has to do something with piston-descending air displacement and it cannot travel a vent if clogged with oil.
2. What if the vent standpipe has a pinhole or worse a big hole in it somewhere below the normal oil level? Oil will constantly drain back down the vent into the engine.
3. What if the oil return standpipe leans over to touch the vent standpipe either by manufacturing defect or coming loose from vibration? Well, gushing oil returning to the oil reservoir will splash into the vent stand tube. Oil blowby has found another source to overwhelm the breather system.

Diagnosing a defective internal oil tank standpipe component is difficult because it is unlikely the mechanic will see anything with a flashlight. However, it never hurts to try especially if the tank is empty and out of the bike. However, there are diagnostic methodologies, which I will relate.

First:

1. Ensure oil level is to specification.
2. Leave ignition off.
3. Temporarily block the oil tank vent line fitting at the engine.
4. Remove vent hose from the engine vent fitting (nipple).



2006 Dyna plus 2007-to-present Twin Cam
TC96, TC103, and CVO 110 Oil Pump

Pictured is a 2006 Dyna/2007-to-present Twin Cam oil pump (26037-06) mounted on its pinion shaft. The pump is internal, sitting between the right engine casing timing-compartment-wall and bolted to the inboard side of the fixed cam-support-plate (not shown). Its enclosed geroter sets, feed and return sit on the rotating flywheel pinion shaft that extends into the timing chest cavity. The oil pump housing remains stationary, bolted to the support plate while the inside-geroters turn with the rotating pinion shaft. The 2006 Dyna-2007 Twin Cam pump is similar to its 1999 to 2006 (except 2006 Dyna) counterparts but pumps 10% more feed oil and scavenges 23% more return oil. However, the pumps do not easily interchange with each other (see The Andrews Solution in Chapter XII). The thinner pressure feed-side geroters (28281-06) are visible. The thicker return-scavenging-side geroter set (26278-06) is behind these and housed on the opposite side of the pump. The new pump has a 10/11 geroter nub arrangement; the outer geroter has eleven inward-facing nubs that interact with the ten outward-facing nubs of the inside geroter, which gives it the increased capacity since the earlier pump has a 13/12 geroter nub arrangement. The outside diameters of early and late geroters are the same. Therefore, with fewer nubs, the extra space created between inner and outer geroters allows more oil in that generates the extra pressure on the feed side geroter set for 10%-more oil feed. The same applies with the return geroter set where the extra space created by fewer nubs generates 23%-more oil return (scavenging). Shouldn't the percentage increases be the same for both feed and return? Yes, except the return geroter set is thicker than the feed geroter set and therefore, handles more oil volume, which creates more return oil pressure. Oil is fed between the geroters, becomes trapped, and is squeezed into a diminishing space as the geroters mesh together eccentrically to create high oil pressure and high volume. Notice the two 1"-inner diameter rear cam journal bearings (H-D 9215) above the pump. Previous 1999-2006 Twin Cams used smaller .875" inner diameter bearings (H-D 9198).

5. Set bike in upright position.
6. Direct the oil vent line to an oil pan or into a bottle.
7. Allow oil, if any, to trickle out into pan/bottle until it stops.
8. Recheck oil level.
    a) If it is down, there is a problem with a standpipe.
    b) If not down, all is okay so far but proceed with next diagnostic test.

Next:

1. If no oil came out the vent line in the first test, leave the line disconnected.
2. Cap off the engine vent fitting as it will still vent and it won't be clean air.
3. Start the bike.
4. If no oil comes out of the vent hose, proceed with the next test.
5. If oil comes out, we may have a tilted return standpipe, whose top lies beside the vent standpipe.
6. To confirm, switch the oil return line with the vent line at the oil tank/reservoir.
7. If there is oil coming out of the vent hose, replace the oil tank.
8. If no oil comes out then the problem is not in the oil tank.
9. Reconnect the oil lines properly; vent to vent and return to return.

Next:

1. Disconnect the oil return line at the engine and immediately plug the hose to prevent residue oil loss onto your shoe.
2. Bypass the return system by cutting a new length of hose, ensure there is no internal blockage, and fit onto the engine return nipple. Feed line up and into the oil tank filler neck.
3. Start and run the engine.
4. If oil carryover diminishes or stops, the problem is between the oil pump return fitting and the oil tank in the oil line.

[1] S&S Cycle, Inc. 2007. *Performance Guide For 199-06 Big Twins with Twin Cam 88® and Twin Cam 88B™ Engines.* S&S Cycle, Inc. catalogue. Page 16.

[2] Ibid., Page 17.

[3] Doherty, Tim. Doherty Machine. Part of interview with Tim Doherty 2006.

[4] Ibid.

[5] Ibid.

CHAPTER V

Twin Cam Lubrication

An air-cooled engine presents special challenges for engine lubrication. A liquid cooled engine like the V-Rod can control engine heat as well as the range of that heat. This assists oil in the performance of its four functions with a higher degree of stability and efficiency.

The vagaries of outside ambient temperatures and the duress placed on an air-cooled engine with different riding conditions puts oil through its paces. Heat increases oil oxidation, which breaks down the oil as well as depleting necessary additives.

Before I explore my opening statements further I will begin to explain lubrication basics. There are two main types of lubrication: oil and grease. Which form is used depends on three factors:

1. Speed of rotation or oscillation.
2. Operating temperatures
3. Whether heat has to be removed from the area of lubrication.

If a function of the lubrication is to control or cool friction-generated heat, then preference will be given to oil, which can flow away thereby dissipating heat. Recirculating oil will provide relative coolness. Therefore, oil is used when the speed of rotation and temperatures are extreme, as inside an air-cooled engine like the Harley-Davidson Twin Cam.

Grease

Grease is used when a bearing operates under normal speed and temperature conditions. An advantage is that grease is less expensive although cost should not be a concern on a motorcycle like Harley-Davidson, where a need for quality should dominate price. More important advantages over oil are that grease:

1. Offers better adhesion.
2. Provide shield against dampness.
3. Affords a guard against external impurities.
4. Although the best quality grease is designed to fight water as in condensation or normal rain, nothing can protect against the nozzle of a high-pressure jet hose that riders love to direct at vulnerable weeping wheel seals. I find water in the oddest places like transmissions and clutches because of the penetrating capabilities of pressure washers.

Grease is standardized and classified by the NLGI (National Lubricating Grease Institute). They use a numbering system ranging from Number 0 to Number 6 that ranks the consistency of the grease.

The higher the number equals a higher solidification.

- Special purpose grease may contain friction reducers like Moly, more correctly named molybdenum in the form of molybdenum disulphide (MOS_2).

- Grease with corrosion resistance additives like Permatex ANTI-SEIZE Lubricant is desirable for rear fork swingarm pivot shafts like those found in FLT and FXR rubbermounts. It is necessary to prevent seizure of mating pivoting parts from corrosion.
- Multipurpose grease with a NLGI Number 2 or NLGI Number 3 rating is most commonly used on a Harley-Davidson.

Common Mistakes of the Harley Rider

A second trait of Harley riders is that bigger is better or more is mandatory. This gluttonous attitude is reflected in:

1. Too-big cams that produce less power.
2. Bigger carburetors that deliver too much gas.
3. Louder exhausts that decrease horsepower.

In terms of lubrication, riders love to overdo their perception of quality.

The almost religious use of 70-weight oils by pre-Evo riders. There is no known use for 70-weight oil and it's only produced for marketing reasons to satisfy customer demand, not a Harley engine's needs. I explain this ad infinitum to customers in my store, but it remains a best seller. Its use just makes the owner feel better and feeling good is what it is all about. However, on initial engine warm-up, the oil's viscosity may be too heavy to penetrate smaller oil feed passages immediately.

1. Instead of using recommended grease or reading the can to see if it is appropriate with say, wheel bearings, the rider will purchase too thick a product or a pretty one that is a nice blue or red color that's too stiff or inappropriate for the use at hand. On initial takeoff the bearing rollers must accelerate too rapidly under load and instead of rolling or turning, they may slide. As they slide, they cut through the all-important lubricating film that separates roller and mating race; now we have metal against metal, causing hidden damage.
2. Sometimes the product is better but not necessary. Synthetic grease is definitely superior. Use it if you like, although the reader should realize that its primary advantage is low frictional resistance at low temperatures down to -70°C. If you ride in that kind of weather you are a better person than I.
3. There are products that will increase longevity and reliability. For example, Harley has taken a huge step forward and first started using black Teflon coating from the rings down on Sportster pistons to assist in break-in and decreasing friction robbing heat. H-D expands this use to Twin Cams in 1999. Also new are bottom end roller cages having a slippery copper like coating on them for the same purpose.

As a generalization for oil usage, choose a 20W-50 name brand detergent synthetic that has an API rating on the container which says SG, SH, SJ, or SL. Use synthetics in a Harley-Davidson only after the engine has been broken in. Break-in currently requires fossil oils. However, this will change over time as engine materials and fitment will become more sophisticated and will adapt to synthetic use for break-in as well as daily application. Many automobiles use synthetic oil exclusively, Corvette being one that comes to mind.

Crude Oil Fractionalization Creates Many Products

A crude explanation, pun intended, for oil products produced from fossil oil is dependent on:

1. Heat.
2. Molecular size.

Fractionalization

After pumping crude oil from the ground, it is refined (distilled) into usable fractions or components at a refinery. I use the words fraction and distilled because the process of distillation separates the crude into fractions based on different boiling points and molecular size, which relates directly to the boiling ranges. The crude is heated until each fraction boils off as a vapor, and allowed to condense through lower temperatures. Further refinement and processing occurs including the addition of additives or additive packages for specific usage. In general:

1. A lighter or smaller molecule will boil or vaporize sooner (less temperature) than a larger molecule. Similar molecular structures based on size and boiling point will produce similar products.
2. The products basing on similar molecular size and boiling point will also be more stable since the base structure of each fraction is similar.

Fractionalization is the term used for the temperature-molecular size separation of differing products from the base crude oil. However, the molecules are not all identical thus affecting the stability and quality of the product refined.

Therefore, there is a mixture of hydrocarbons in each product refined. Although infinitely more stable and uniform than the crude it derives from, *the lack of a high consistent stabilization like that found in synthetic oil is also the weakness of fossil oil.* The total lack of uniformity allows the fossil oil to deteriorate with greater rapidity than a synthetic. The heavier fraction molecular structure portion in a particular product will result in impurities for that particular functioning purpose. Conversely, the lighter fraction molecular structure portion present in a given product will result in volatization or boiling off of the lighter molecules.

Crude oil is heated to separate component parts depending on molecular size. At approximately 350^0 C (662^0 F) the largest molecules will separate into Bitumen that has use for paving and roofing materials. These molecules have the following properties:

1. High boiling point.
2. Low volatility.
3. Will ignite with difficulty.
4. Has a very low flow rate.

At approximately 25^0 C (77^0 F) the smallest molecules will separate having the following properties:

1. Low boiling point.
2. High volatility.
3. Will ignite easily.
4. Has a high flow rate.

The order of crude oil based products that separate from the hottest temperatures to the coolest ones and largest to smallest molecules are:

1. Bitumen (asphalt).
2. Fuel Oil.

3. Diesel Oil.
4. Kerosene (airplane fuel).
5. Naphtha (chemical production)
6. Gasoline (automotive/motorcycle)
7. Refinery gas (bottled gases).

Oil has Four Jobs

What is oil supposed to do in your Harley? It has four basic functions:

1. *Cooling* by dissipating and carrying away heat caused by friction of parts moving together and from the heat of combustion.
2. *Cleaning* by carrying contaminants produced by friction and combustion to the oil filter. Yes, it's difficult to do this without a filter.
3. *Lubrication* by having a film of oil between moving parts to reduce friction.
4. *Sealing* by oil prevents oil leakage past seals and rings. A rubber seal cannot keep oil in or out without having a film of oil to assist it.

The lubrication of an H-D motor currently being broken in must be done with a fossil product free of slippery additives. Rings, for example, have to break through the oil film occasionally to scuff the cylinder wall to form mating surfaces that wear in together.

This is why the super slippery additives can only be used after break-in. The same situation exists with synthetic oils, though neither is necessary for your Harley under normal operating conditions. I had to say that synthetic oil is not necessary for your Harley after break-in but I don't like saying this.

However, I highly recommend synthetic oil use for all Harley-Davidson's once the engine has 1500 miles (2400 kilometers).

- Furthermore, if considering the use of extra miracle synthetic lubricants or additives, don't believe everything you hear. Research the product you are considering after you decide what problem you are trying to solve. I am not against supplementary additives but feel everything the engine needs can be found in a variety of top-grade synthetic oil brands.

Fossil, Synthetic, and Semi-Synthetic Oil

I will give a short explanation for all three types of oil. I will explore each in depth as they relate to Harley-Davidson and specifically the Twin Cam as the chapter proceeds.

Fossil Oil

Fossil or mineral fuel is the most natural of the three since it comes out of the ground. I use the term fuel instead of oil since coal and natural gas also forms from much the same source.

The word fossil derives from the anaerobic decomposition of dead organisms. Anaerobic defines as without oxygen. Therefore, fossil oils formulate without the benefit of air. However, according to Biogenic Theory, the presence of heat and pressure is also necessary for the formation of fossil fuels. Heat and pressure is much the same thing since expanding heat creates pressure. The flip side is that pressure creates heat. Therefore, the pressure and heat generated by the weight of deposits above does not happen for eons. This process is an extremely slow one that takes millions of years, which is the primary reason for its depletion as a renewable resource. Mankind is using the fossil fuel resources up very much faster than they can regenerate. Some fossil fuel is 650,000,000 years old.

Fossil fuels main composition derives from carbon (C) and hydrocarbons (HC or hydrogen carbon). The range of fossil fuels depends on the percentage compositions of carbon and hydrocarbon.For example:

Methane's volatility derives from low carbon to hydrogen ratios.

1. Oil has a higher but still low percentage of carbon to hydrocarbon, which leaves it volatile but not explosive.
2. A nonvolatile coal like anthracite is almost pure carbon.

However, most fossil oil needs much refining after leaving the ground. Some of the purest oil in the world comes from Pennsylvania, USA. The dirtiest is probably from the Canadian tar sands in Alberta, with Texas and Mid Eastern crude in the middle. By the time fossil oil (petroleum) is suitably refined with additive packages to enter a Harley-Davidson or other vehicle it is a long way from pure. It is a chemical soup introduced to its natural base of carbon and hydrocarbon fossilization.

Mineral oils are complex mixtures of *naturally* occurring carbon and hydrocarbons.

The Original Syn

This manmade oil is synthesized from chemical compounds that do not derive from fossilized petroleum. This artificially made lubricant substitutes wonderfully for crude mineral oil. In my humble opinion, synthetics provide superior mechanical and chemical properties than those found in natural fossilized oil.

The origins for synthetic oils came out of necessity from Germany and America during World War II. For Germany, this war-technology derived from a lack of resource fossilized oil to indefinitely drive their war machine. The superiority of synthetic oil made for advanced and reliable airplane engine maintenance and durability made its development essential.

The first synthetic oils marketed for automotive use and therefore, eligible also for motorcycles occurred during the mid nineteen-sixties. Chevron was probably the first to do this, closely followed by a company called Synlube who introduced "The Original Syn" in 1969. NEO Oil Company followed a year later. A familiar company name evolved from All-Proof to form Red Line, which introduced its full synthetic in 1971. This was closely followed by a very familiar and popular manufacturer for synthetic oil, Amsoil for Harley-Davidson's as well as a host of other uses. Synthetic oils are synthesized or manmade by combining individual elements or compounds into integrated entities that are tailored to have a controlled molecular structure with predictable properties.

American Petroleum Institute (API)

The American Petroleum Institute (API) began the classification process that enables reading the oil can to determine if oil is suitable for the internal combustion engine. Part of the classification system categorizes the different chemical base oils into API Groups, I through V.

Mineral (fossil) based oils are classified as Group I, Group II, Group II+, and Group III API classified oils

1. A Group III base mineral oil is sometimes classified as a synthetic but officially remains the top level fossilized or mineral oil stock.

2. API Group III base oils go through a process called hydrocracking or hydroisomerization. This involves a catalytic conversion of feed mineral base stocks under pressure in the presence of hydrogen into higher quality mineral lubricating oil. In 2005 production of gas-to-liquid (GTL) Group III base stocks began. Even though they may be considered a synthetic product they are still mineral base stocks and counted as the mineral part of all semi-synthetic lubricants.
    a) A PAO (polyalphaolefin) base for synthetic oil classifies as an API Group IV oil base.
3. Non PAO synthetic esters (diesters, polyolesters, polyglycols alklylated napthlenes, and alkyklated benzenes) classify as an API Group V synthetic oil base.

I will be discussing API further on in this chapter in the section: *Reading the Oil Can.*

Semi-Synthetic Oil

Semi-synthetic oil also known as synthetic blends is more economical than synthetic oil and offers some of the advantages of the synthetics. Motul introduced the first semi-synthetic oil in 1966. Semi-synthetic oils are blends of mineral oil with maximum 30% synthetic oil content. Group I, Group II, Group II+, or Group III mineral oil will normally be the base stock for semi-synthetic oil. Some even use the Group IV PAO synthetic base stock as a foundation. The mineral base stocks as well as the PAO base combine with chemical compound additive and performance packages to form semi-synthetic oils.

Over the years many oils used in Evolution and Twin Cam transmissions have been semi-synthetic with the exception of H-D Syn 3 oil, a full synthetic, while primary fluids have traditionally been fossil oil. H-D discouraged the use of synthetic oil in their motorcycles because they felt they had not been tested adequately for use in the Evolution motorcycle. The Factory quite rightly discouraged its use for the reason stated but also to garner more market share for their repackaged fossil oil. The Motor Company thinks that synthetic oil is wonderful now that they have their own Syn 3 SAE 20W-50 synthetic oil.

Syn 3 Oil vs. Using Gear Oil in H-D Transmissions

Although it has been my experience that 80/90-gear oil works better in a Big Twin transmission than Syn 3 20W-50 oil specifically in eliminating gear whines: others have had the opposite experience. They say Syn 3 cured a whine in their bikes that occurred when using gear oil. Service managers at dealerships have told me that H-D has advised them to replace Syn 3 with gear oil if there were noise issues like whining. While many think 80/90-gear oil is heavier than the 20W-50 Syn 3, I should explain that when both test at 100 degrees Celsius (212° F); 80-weight transmission oil is roughly equivalent to 20-weight engine oil. Furthermore, the Syn 3, SAE 50-weight oil component will test roughly the same as 90-weight gear oil. However, the viscosities between the two vary at lower temperatures with the 80/90-gear oil being more viscous. Many riders like to substitute the words heavier or thicker for viscous.

However, there are good reasons to use gear oil since they utilize additives like sulphur. Sulphur compounds create acids in engine oil that preclude their usage. Herein lays the major difference. I feel very uncomfortable using the same oil like Syn 3 for three different applications that have specific and independent needs. An engine is hot and dirty, a clutch needs cooling with lubricity for primary chain components, and transmission gears chop up molecules. Additives that help one area may be detrimental in another.

I guess that the icing on the cake is that Harley-Davidson has a new recommendation to use a newly developed formulation for their primary chain case and transmissions. It is Formula+ H-D 99851-05. However, I still currently prefer specialized oil for each. I never say never because technology inexorably marches on.

Synthetic Oil Disadvantages

1. Synthetics are currently unsuitable for engine break-in purposes where some friction is required for mating parts to wear together. This is hardly a disadvantage but a testament to the lubricity of synthetics. Modern manufacturing methods, superior metallurgy, and parts coatings like Teflon coated piston skirts are making break-in procedures less necessary. Many performance cars come with synthetic oil from day one for these reasons. Harley-Davidson Evolution or Twin Cam motorcycles do not broach this plateau. However, the Twin Cam is much closer. I am sure the V-Rod will broach new frontiers first.
2. Leaded fuel vehicles may better served with fossil oil because synthetic oil's do not suspend lead dirt as well. The Evolution and Twin Cam motorcycles are designed to run on unleaded fuel so this is not a consideration.
3. However, expense is the big issue. Synthetic oil is much more expensive than fossil oil although that gap is closing somewhat with the spiraling costs of fossil oil present day.

Advantages of Synthetic Oil

1. Synthetic oil has superior lubrication *particularly on cold starting*. Damage can occur on cold starts especially with fossil oils because the oil needs to warm up before it flows at best capacity. Therefore, parts can starve for lubrication during the first few minutes of engine running. Synthetics flow more readily, consistently, and faster when cold.
2. This oil will also cling longer to parts before draining away, which is advantageous for the next startup.
3. Synthetic oil is more *resistant to oxidation*. This is the big advantage. Heat destroys oil's capacity to lubricate. Thermal breakdown creates oxidation.
4. Synthetic oil has better viscosity performance for both low and high temperatures. This means that viscosity is more consistent in cold situations where fossil oil will *thicken* and resist flow and hot situations where mineral oil may *thin* too much. In other words synthetics maintain consistency with temperature extremes.
5. Synthetics have superior chemical and shear stability. Straight cut gears in particular do a wonderful job of chopping up (shear) fossil oil molecules. Synthetics resist the ravages churning parts and heat can cause to their molecular structure.
6. Small but measureable improvements in fuel economy occur with the use of synthetic oil all other factors being equal. There is less frictional loss of internal horsepower because parts move together with less resistance.

7. It follows that small but measureable improvements in performance occur with the use of synthetic oil all other factors being equal for the same reason as fuel economy improves. There is less frictional loss of internal horsepower because parts move together with less resistance.
8. Decreased evaporative loss becomes more important as time marches on and EPA constraints become stricter.
9. Finally, synthetics create less sludge problems. Sludge is the residue left inside an engine from the dirt of the combustion process in combination with internal parts wear, and oil oxidation.
10. Some experts advise increasing synthetic oil (change) drain intervals and tout this as an advantage. I beg to disagree.

The Mythological Bearing Skid

Finally, to counter a pervasive mistruth propagated by the fear mongers, there is no known case of bearing skid with the use of synthetic oil. As of this writing in 2010, no one really believes this anymore. However, back in the Evolution and Shovelhead days, misinformed wrenches and mechanics sometimes propagated this myth as they argued in favor of fossil oil over synthetic oil. I have taken the trouble over the years to ask various bearing and oil companies that supply Harley-Davidson like the respected Timken. From the truly knowledgeable, not one could recall ever seeing this skidding condition caused by oil.

This myth derives from the slipperiness characteristic of synthetic over fossil oil. We want slippery. We want to reduce power robbing and parts wearing friction. We also want the superior film strength of oil that separates moving parts, sometimes only molecules thick. Synthetic is tough; its film strength and slippery attributes protects the engine better than fossil oil.

I have seen bearing skid from other causes, notably oil starvation and bearing cage wear, particularly with bottom end bearings. The loose cylindrical rollers are guided by the bearing cage they fit into. Evolution motorcycles use three sets of 17-rollers with Twin Cams utilizing three sets of 18-rollers in the bottom end. If the cages are allowed to wear way beyond tolerance before replacement, the rollers will no longer be guided true to the crank pin on the inner side and the connecting rod race on the outer. The bearing will be able to shift off-kilter, jam in the cage and begin to drag or skid instead of rolling. This effect will flatten the skidding sides of the roller in extreme cases of neglect. It is all downhill from there. If allowed to continue for much longer, the bottom end will seize, break loose from the force of the rotating flywheels, repetitively seize and break loose again until something will fracture. I have seen connecting rods snap in half and blow out the bottom half of the engine cases. Lack of lubrication and wear induced bearing skid is very common in Panhead and Shovelhead engines, less common in Evolution engines, and I have yet to see a bad case in a Twin Cam engine eleven years after its inception. This is due to superior:

1. Oil pumps with improving design supplying consistent pressurized oil; steel bodies (Pans and early Shovels) to aluminum bodies (late Shovels and Evolutions), and gears to geroters (Twin Cams). Gear driven pumps provide moderate pressure and moderate volume whereas geroters provide high pressure and high volume. Aluminum bodies give more precise fitment and thus pressure while steel bodies allow some leakage.
2. Oil filtration; small rock filtration (Pans and Shovels) to 30-micron (Evolution), 10-micron (TC88), and finally 5-micron (TC96, TC103, CVO 110) filtering.

3. Bearing cages; open cast iron (Pans, Shovels), aluminum closed end (late-Shovels, Evolution), precision metal (mid to late Evolution) and the Twin Cam closed end, *captured*, and copper-coated bearing cages.

Furthermore, synthetic oil would protect this situation from occurring longer than fossil oil.

Oil Change Intervals

How often should a Harley rider change the Twin Cam motorcycle's oil? The various manuals advise after the first 1000 miles (1600 kilometers) and then every 5000 miles (8000 km) thereafter. Personally, I like to change the oil and filters more often but I can be a little anal on this subject.

Synthetics and Drain Intervals

Many experts tout another cost effective advantage of synthetics is that drain intervals can be extended. Most people in the industry originally agreed with this hypothesis because of synthetic oil's higher resistance to oxidation and thus breakdown. However, dirt is dirt and it must be flushed out of the engine. Some say this is the oil filter's job. Until the advent of the Evolution, oil filtration was not very good in Harley-Davidson motorcycles. The Evolution brought the introduction of the 30-micron filter. This filters the majority but not the entire residue and dirt being carried away by the oil more than 30-millionths of a meter in size. The Twin Cam 88 uses a 10-micron filter (63731-99 black; 63798-99 chrome) while the TC96, TC103, and CVO 110 use a 5-micron synthetic media filter (63731-99 black; 63798-99A chrome).

The 10-micron filter will filter the majority but not all of the residue and dirt being carried away by the oil more than 10-millionths of a meter in size.

- The 5-micron filter will filter the majority but not all of the residue and dirt being carried away by the oil more than 5-millionths of a meter in size

As oil filtration and internal engine heat control improves, then logically oil drain intervals can extend:

1. I do not believe in extending oil drain intervals just because synthetic oil is being used.
2. However, I do believe synthetics will better withstand the ravages an internal combustion engine can impose.
3. Furthermore, I think the reasons drain intervals have increased over time are:
    a) Unleaded gas runs much cleaner while previous use of leaded gas dirties and corrodes whatever it comes in contact with.
    b) Improved electronic ignitions that control sparking and heat generation more accurately. In other words, electronic ignitions can retard timing slightly to control the onset of heat generated detonation. Ignitions advance timing for engine efficiency until the onset of destructive detonation then back away to control it.
    c) Oil coolers. I am a firm believer in their use in hot climates since they lower oil temperatures and thus oxidation rates.
    d) Oil filtration has improved.

e) The Evolution holds much of its heat inside the engine to be carried away with the oil. The Twin Cam has larger finning and designs to dissipate some of its internal heat externally. The rider may feel that the Twin Cam runs much hotter because of this but the engine is well served because of it.

I am not a proponent of extending drain intervals for an Evolution engine because the technology to allow this is not quite there yet. However, there is good reason to extend intervals with the Twin Cam, particularly after 2006 with improved filtration and an excellent running engine management system. However, I do not believe in extending drain intervals beyond the H-D recommended 5000 miles or 8000 kilometers.

Extend Oil Life by Filter Changes?

Another fallacy that some believe is that doubling up on oil filter changes alone will extend oil life making it unnecessary to change the oil at recommended intervals. The rationalization falsely believes that this will remove a higher percentage of sediment, dirt, and chemical byproducts from the detergent oil. Logically, it probably does but not at a significant level. If the oil is that dirty, then both oil and filter need to be changed sooner rather than later. I will explore some reasons for early fluid and filter changes as we proceed.

First, let's put to bed, why more frequent filter changes will not extend oil-life. Of course, it is essential that particulate suspended in the oil is filtered efficiently; this much we can agree on. However, it is the breakdown of additives in the oil package that is the concern. All the filtering in the world cannot appreciably prevent the chemical breakdown of additives as they do their job.

If the detergent component of the oil-package loses effectiveness, then how will dirt suspend in the oil for filtration purposes?

- The same can be said for other additives that specifically reduce friction like Moly or phosphorus or zinc. Friction and thus wear become a major concern as these additives deplete.
- Finally, how about the *pour point depressant* additives that reduce wax crystallization of oil at lower temperatures? These will ensure the oil stays fluid.

As I proceed and explain other additives, the reader will become very nervous about their possible depletion with extended oil usage.

Filter Change with Every Second Oil Change?

Well, I guess if a rider is too cheap to change the filter every time with a fluid change, then he or she is also too cheap to buy a Harley-Davidson. It is true that:

1. As I have said, H-D engines run cleaner and produce less internal pollution with the advent of unleaded gasoline. Leaded gas is very dirty. It is so corrosive that it lessens spark plug electrode life and eats away at muffler internals.
2. Twin Cam engines also produce less wear debris because of superior metallurgy such as hypereutectic piston composition and better internal design such as angled connecting rods and improved angularity of valve guides. Improved angularity reduces side-thrust thus lessening wear and heat.
3. The filtration itself becomes very much more efficient with the advent of first, the TC88 engine and then increases with the TC96, TC103, and CVO 110 engines.
4. The quality of oil and its additive packages continues to improve also.

5. As the years progress into the Twin Cam era, parts metallurgy and protective friction-lessening coatings reduce wear particulate to the lowest levels ever for the Big Twin.

However:

1. An air-cooled engine must deal with temperature changes that manage easily with liquid-cooling. H-D temperature changes cause a higher percentage of internal chemical reactions and wear whose debris must be filtered.
2. The best oil filter to date is the 5-micron filter. It filters a higher percentage of particulate than previous filters. Once the filter pores clog, filtration effectiveness lessens. In extreme circumstances, free oil flow through the filter can also be an issue.

Harley-Davidson is going to great lengths to continuously improve its motorcycles. Riders must do their part also through regular maintenance that includes oil and filter changes. If possessing that magical Twin Cam that has a million miles in her heart, she will not get there without the lifeblood of fresh oil and the kidneys of filtration.

Oil Consumption Rates

With the advent of the Evolution, riders began to expect less and less oil consumption. I have seen many riders who feel something is wrong if they do not get 5000 miles before losing a quart of oil. What can I say? There are many Evolutions and Twin Cams that enjoy this wonderful low oil consumption rate. However, if there are no leaks, which includes weeping, and there is no blue or white smoke emanating from the exhausts, a Harley dealer is not going to get excited about a perceived consumption problem until broaching about 1000 miles per quart of oil and some less.

I agree the divergence between these two figures is excessive. My advice is that the problem of perceived excess consumption may lie elsewhere. Oil consumption will increase with:

1. Hard fast riding. Increase oil consumption by riding normally. If not wanting to modify riding habits then the rider will use more oil.
2. Towing a trailer and/or carrying a heavy load will increase oil consumption.
3. If the oil tank is not full, the enemy heat will rise and oil consumption will increase.
4. If the tank is too full, there will not be enough air for tank pressurization to function properly. Oil will be forced out the weakest area until sufficient air exists. Of course, this may also damage a seal, which will continue to deplete oil.
5. Engine tuning can help or hinder oil consumption. Too much ignition advance will create detonation through excess heat, which will increase levels of oil consumption.

Engine Wear and Disappearing Oil

Consider the following:

1. A fresh engine will burn more oil than a broken-in one because mating parts have not adjusted to each other fully and with the example of piston rings do not seal in all the oil. Break-in will use more oil but it will not be noticeable use except on the dipstick.
2. A properly broken-in engine will use the least oil as all parts including piston rings and seals are doing their job with maximum effectiveness.

3. As an engine wears, tolerances between parts increase as well as seals begin to lose some of their initial effectiveness. This will result in higher oil consumption before tell tale leakage and combustion oil smoking

Noack Volatility and Disappearing Oil

If a Twin Cam motorcycle or any other vehicle for that matter uses oil but:

- There are no oil leaks.
- No oil-smoking past the piston rings or valve guides.
- The bike is ridden normally in mild weather.
- The bike is in proper tune and is properly maintained.
- Look no further than volatization as the probable reason. Volatization in an engine defines as lighter molecules vaporizing or boiling off and heavier molecules remaining. This, of course, leads to higher oil consumption and will explain why one bike uses more oil than another.

Engine oil is fractionalized at the refinery but is not that consistent. A refinery fractionalizes crude oil into broad categories depending on temperature boiling points and molecular size. Different refineries may also have fractionally different byproducts boiled from crude. One batch of engine oil may vaporize more than another batch thus causing slightly higher consumption. This is why a hotter running engine that is not tuned correctly or running in high ambient temperatures will have a higher consumption rate. Lighter molecules in the oil will vaporize.

The Noack Volatility Test establishes the amount of weight loss an oil experiences through volatization. The tested oil is heated to 150^0 C (302^0 F) for a set time period. Lighter oil molecules will fraction or boil off. The Noack testing determines the percentage lost, by weight, due to this measured fractionalization.

Oil Volatization Creates a Viscosity Change

Oil has a graded viscosity level when leaving the refinery. If there are a higher percentage of lighter molecules present in the oil they may vaporize with use in an engine. The net effect is that a heavier molecular structure remains changing the oil's viscosity to a heavier oil. This thickening may affect flow rates in small oil passages. Synthetic oils have very low vaporization rates when compared with fossil oils.

How Often Should Oil be changed?

The combustion process creates a dirty world hidden by a veneer of sparkling chrome. Fresh oil is immediately attacked from all sides by pollutants, heat, and condensation to name a few of the enemies.

The standard 5000 miles (8000 kilometers) listed in most manuals for Twin Cam motorcycles is only a guideline for normal riding in ordinary conditions. I use this mileage figure as the maximum without replenishing the engine's lifeblood. I have discussed the major reason to change oil is that the additives that extend engine life gradually deplete with normal riding. I did not state the corollary that under adverse riding and climatic conditions that the various additives will deplete even more rapidly necessitating more frequent oil and filter changes.

For example, the detergent additives that are very necessary for your Harley suspend dirt and crud particles in the oil to be removed by the filter. As the detergent is depleted, the particles are deposited inside the engine and form sludge. When sludge is found while rebuilding an engine, this is an indicator that the owner hasn't been changing fluids often enough over a long period of time.

Most mechanics would agree that the oil couldn't be changed too frequently to ensure the longest engine life possible. However, let's not get too anal with this and find some balance. Every couple of hundred miles would be a waste of money but cutting the Factory's recommendations in half is a time-honored tradition followed by many.

During break-in, I change my oil after 50 miles and every 250 miles up to 1500 miles when the engine will be broken in. After that, I used to change it every 2500 miles. Now, I might do it every 3500 or 4000 miles. However, there are many mitigating factors as to when oil should be changed. Change the oil and filter more often if:

1. Using leaded gas despite its good points is destructive in other ways. It causes excess dirt and rapid corrosion. More to the point it also dirties the oil and breaks it down. It is obvious that Harleys using leaded gas should change their oil more frequently than those using unleaded.
2. Extreme heat from either internal or external sources is the *big* destroyer for lubrication. Heat causes oxidation of the oil, which destroys its lubricating properties.
    a) External heat refers to riding in temperatures in excess of 80° F in areas like the U.S. Midwest or South during summer months.
    b) Internal heat denotes excessive temperatures due to improper ignition timing or restricting the normal cooling air flow around the engine fins.
3. Riding a lot on dusty or gravel roads increases dirt intake, which dirties both air filters and oil.
4. Trailer towing requires more work thus causing more strain on the engine that in turn generates more heat, which will break down the oil in less time.
5. Long hours of high speed touring will work the engine hard, which will increase oil breakdown. I ride like this. The Twin Cam can take hard riding in stride but I change the oil more frequently because of my aggressive habits.
6. Riding on and around sand whether it be in the desert or on the beach necessitates more frequent air filter and oil/filter changes. Riding on sand by salt water necessitates even more frequent replenishing.
7. Living in salt water coastal areas will allow in corrosive salt from exposure to salt air.
8. Extensive idling creates unnecessary heat for an air-cooled engine, which breaks down the oil faster.
9. Riding in rush hour traffic on hot summer days does not bode well for the oil in an air-cooled engine.
10. There are a couple of oil-hurting situations left that I will cover in more detail but first, contrast the above-listed riding conditions with moderate speeds on a properly tuned Twin Cam on an open highway on a cool Fall day. The need for oil change intervals changes dramatically. Oil change intervals should tailor to specific conditions. The average interval suggested by the manual may *not* be appropriate for your riding style or when mitigating circumstances occur beyond control.

Short Trip Riding Requires Frequent Oil Changes

When a customer tells me that they don't ride much and when they do, it only involves short trips, I have to explain why this type of riding can be injurious to the engine if the oil is not changed more frequently. The customer is quite right to argue logically that fewer miles indicate the oil is still functioning at 100%. Consider that with this type of riding, neither the engine nor the oil reaches normal operating temperatures. The higher temperatures produced by a longer trip are required to boil off the condensation and unburned byproducts from the combustion process. Therefore, more frequent oil changes are required.

Cold Weather Necessitates More Frequent Oil Changes

Cold weather riding is all about the buildup of water vapor and condensation. An internal combustion engine will produce water vapor via chemical reactions, temperature changes, as well as through the humidity in the air.

Initial cold weather starting will convert the internal water vapor to water as it condenses. Of course, as the engine heats up, it will boil off the water and the vapor will exit through the breather. Therefore, an engine that is started and run for short periods in colder weather will begin an accumulation of water because the engine is not run long enough to vaporize and exhaust it through the breather.

The water will begin to accumulate in the crankcase as well as the oil tank. The water will then mix with the oil to form sludge. This oily sludge will pump into the engine and begin a premature wear situation because of clogging and less lubricity. Therefore, change the oil more frequently in colder weather. The reason is simple as condensation boils off faster in warmer weather.

Freezing weather brings additional danger as the condensate will freeze. Engine startup may result in oil passages becoming clogged with not only sludge but ice crystals blocking oil flow. Change the oil even more frequently in freezing weather. Oil changes in cold weather conditions also require cleaning the oil tank and the flushing of oil lines to eliminate any residue, water, sludge and ice crystals.

Furthermore, bikes that are stored outside or in unheated garages over winter freezing conditions must also have careful initial care before starting up in warmer weather. I would change the oil and flush the oil tank and lines before startup. I would then run the engine for about 50 miles and do the same again.

In 1999, the oil interval change periods increase to 1000 miles (1600 kilometers) from 500 miles (800 kilometers) but remain thereafter at 5000 mile (8000 kilometer) intervals. I have experimented with my own bikes and I must confess that the oil stays cleaner longer in a Twin Cam due to Teflon-coated hypereutectic pistons, coated bottom-end bearing cages, and better materials all-round with closer fitment. The Twin Cam is the cleanest Big Twin internal running engine yet.

Lubricating oil and grease is the lifeblood of a Harley-Davidson. They are only to be ignored or treated casually at the expense of your wallet and the detriment of your ride.

Oil Additives

Oil is a chemical soup of elements and compounds that protects the internal combustion engine that includes Harley-Davidson. At this point, I should mention that detergents are doing their job when the oil gets dirty quickly. I often get complaints that the fossil oil I sell dirties fast. That's right; it is only doing its job more effectively. Other additives are necessary to:

1. Maintain high film strength, which is the ability of oil to remain between two parts such as a bearing surface under great pressure. This alone is a good reason to buy a top-quality lubricant.
2. Control the thickness or viscosity of the oil at different temperatures. Heat will thin out oil and, conversely, cold will thicken it.
3. Control foam. As oil splashes around inside the engine it combines with air bubbles and turns into foam. Foam cannot replace oil as a film between parts and the last time I checked air was not a lubricant. Foam will also cause temperatures to rise and that is the real enemy since heat increases the rate of oxidation.
4. Prevent oxidation. Oxidation is when oil combines with oxygen, with extreme heat, picking up water (condensation), rust (oxidation of metal), acids and other byproducts of combustion. It's a dirty world in there.
5. Dispersants (detergents) are used to help prevent sludge formation by dispersing contaminants and keeping them in suspension for oil filtration. Some popular detergents are Calcium (Ca), Calcium/magnesium (Ca/Mg) or Calcium/magnesium/sodium (Ca/Mg/Na).
6. Alkalinity helps neutralize acids formed in the oil by combustion and chemical reactions.
7. Anti-wear agents. These additives reduce friction between mating surfaces. Phosphorus (P) and zinc (Zn) are too low cost favorites. Moly, (molybdenum) is a real good anti-wear agent but is expensive. Of the ten oils we at American Iron Magazine analyzed a few years ago including Harley 360 only Mobil 1, Royal Purple and Torco synthetics had appreciable amounts of Moly additive. These three oils also had more phosphorus and zinc than other oils analyzed.
8. Pour Point Depressants. Got me how they came up with this name. This keeps the oil fluid at low temperatures by preventing wax crystals from forming.

The Additive Package: Automotive versus Motorcycle

Get ready for this information. I quote the now defunct Paramins Post a publication of Paramins who was a leading manufacturer of oil additive packages for the oil companies. Paramins was acquired by Exxon and became Paramins Business Unit and later sold to Chevron and remains an industry leader. Paramins said that "Many motorcycle oils marketed today are nothing more than rebranded car motor oils with no optimization for four stroke motorcycle engines."

Airplane Oil in a Harley-Davidson

Every time I write about oil it stirs up a hornets' nest. I always try to give the reasons for what I say or advise. Nevertheless, no mechanical subject invokes opinionated heated discussion like the subject of oil. I have written a couple of times about airplane oil's use in a Harley-Davidson. The devotees to airplane oil like Aeroshell are religiously loyal. Some will use airplane oil for break-in and then switch to a motorcycle fossil or synthetic oil. Others feel that its use is the best for a Harley-Davidson for break-in and continued use, simply because the standards for an airplane safety are higher.

Logically, an air-cooled gasoline engine in an airplane would use the best-of-best oil for lubrication. This is true. It is also obvious since an engine failure is a life-or-death situation. An engine failure on a Harley-Davidson most times merely involves coasting to a stop on the side of the road. Sometimes logic does not work because there is not enough available information to point logic in the right direction. Yes, an airplane piston-engine is air-cooled. So is a Harley. Do they share the same requirements? Some requirements are mutual while others are not.

Airplane oil lacks some additives that a Harley-Davidson engine requires. The reason is that an airplane cannot risk a fouled spark plug while flying at a few thousand feet up in the air.

Furthermore, airplane oil is non-detergent oil. H-D oil, other motorcycle oils and automotive oils are detergent oils. A detergent additive is required in whatever oil you use in your Harley since combustion forms acids, varnish, and sludge. Combustion is a dirty process. Detergents dissolve these harmful products, neutralizing them and carrying them away.

So, airplanes require a detergent also, do they not? Airplane oil is changed more frequently to get around this.

Would you put Harley oil in an airplane?

Let's ask the question from the opposite vantage point. Would you put Harley-Davidson oil in an airplane? Nope, not with me in it you won't! Two reasons that immediately pop into my head are:

1. H-D oil, other motorcycle oils and/or automotive oils have additives that can possibly foul the spark plugs in an airplane engine. It is not likely, but the possibility exists. When looking from the perspective of millions of miles of flying, then the possibility will become a surety at some point.
2. H-D oil, other motorcycle oils and/or automotive oils are detergent oils. The detergent suspends combustion residue and parts wear for removal to the oil filter. Again, this can cause problems in an engine that needs a perfect safety record. Airplane oil is non-detergent. It is changed more frequently. In addition, the engines are built differently with coated parts and undergo bench break-in procedures to eliminate the period when most contaminants form.

Airplane oil is for airplanes. Automotive/motorcycle oil is for Harley-Davidson.

Heat is the Enemy

An oil temperature gauge in your oil tank or a cylinder temperature indicator running off the head is a good idea particularly if you live in or travel through hot areas. The cylinder head gauge is more accurate than the oil tank one since it hasn't had as much time to cool. Add 10% onto the oil tank reading to get a better indication of engine temperature.

For fossil oil, 250^0 Fahrenheit is the figure to remember and for synthetics allow for around 300^0 F before becoming worried about oxidation. As long as *sustained* operating temperatures don't go above the 250^0 F level, everything is "cool" so to speak. The reader can now see the major reason that synthetic oils are superior for severe operating conditions.

However, please note that there is something else seriously wrong if a reading of 300^0 F is ever indicated even though oxidation will be curtailed more effectively with a synthetic. I am only speaking in terms of oil longevity and ability to resist heat inducing oxidation, which destroys oil effectiveness. These temperatures will cause many other problems. Harley-Davidson's normally run in the 225^0 F range but I like to get it down to around 210^0 F to 215^0 F. I do this by running 10-row Jagg oil cooler on a stock Twin Cam and dual 10-row Jagg oil coolers on my performance Twin Cams.

Heat causes amongst other things, oxidation, which ravages the oil's ability to function correctly causing the oil to break down. Vaporization is another concern that will cause higher oil consumption as well as effectively increasing oil viscosity, which can cause flow problems to all areas of the engine.

Two Modifications for Cooler Twin Cams

There are a couple of simple modifications to ease some of that excess heat that swaths engine and rider alike. The following will also apply to Evolution models.

While heat is an issue with the Evolutions in extreme temperatures, it is minimal when compared to the TC88's. The Twin Cam moves heat to the engine fins, which have 60% more area to dissipate the heat more effectively. Unfortunately, the rider will experience the worst of this on hot days.

Lower Fairing Removal

Removal of lower fairings that hug the crash bars will obviously be the best fix for excess heat caused by inadequate air flow over the engine. However, this is not practical when wanting protection from rain. For some it would also take away from the aesthetic value of the King of the Road.

The FLTR Road Glide with lowers installed is okay and needs no modifications to increase air flow. The Road Glide fairing design is very much superior to Ultra-type lowers from a cooling point of view although Ultra lowers improve air flow in later years. The two types of fairing lowers are not interchangeable.

I visually compared the two lower designs in my service area. I knew they were different, but I never realized just how free flowing the Road Glide was compared to the gross restrictiveness of the Ultra until a year or two ago (new style lowers have vents to direct air at the engine).

Lower Fairing Modification

On Ultra models and FLHT Baggers with lowers installed, there is an impediment to air flow over the engine. Removal of this obstruction is easy. This procedure is outlined in Harley *Service Bulletin M-1096.* It begins with a caution regarding cutting any painted fiberglass. Obviously, it is important not to damage or deface a painted part.

Any mechanic will know to use a very fine hacksaw to ensure the paint remains undisturbed. Cover the cut area with adhesive masking tape. The cut lines are marked with a fine marker or pen. Although the bulletin suggests doing this on the painted side, I like to mask both sides for all the time it takes. The removed section is from the fairing lowers near where the glove box attaches. It is probably best to let your bike shop do this procedure unless you obtain a copy of the bulletin for the instructional diagrams. More air will now swath the air-cooled engine with cooler air removing heat dissipation from the engine finning.

Removing the Front Fork Air Dam

The second fix is applicable for all Evolution or TC88 and TC96 FLT series Baggers from 1984-to-present equipped with an air baffle (dam) part number 58520-79 or 58520-79A. Simply remove the two bolts. (Some models have three bolts that attach the air dam to the bottom fork crown between the fork tube stanchion covers on the front-end forks. You may have never noticed the concave sheet metal air dam that obstructs air flow from flowing under the gas tank and over the heads.

On removal, be careful the air dam does not fall on top of the painted fender. While light, it is capable of chipping paint. Replace the bolts back into the lower fork crown to prevent rusted internal threads. In addition, if wanting to put the air dam back on in colder weather, you will not wonder about where the safe place is that you stored the bolts.

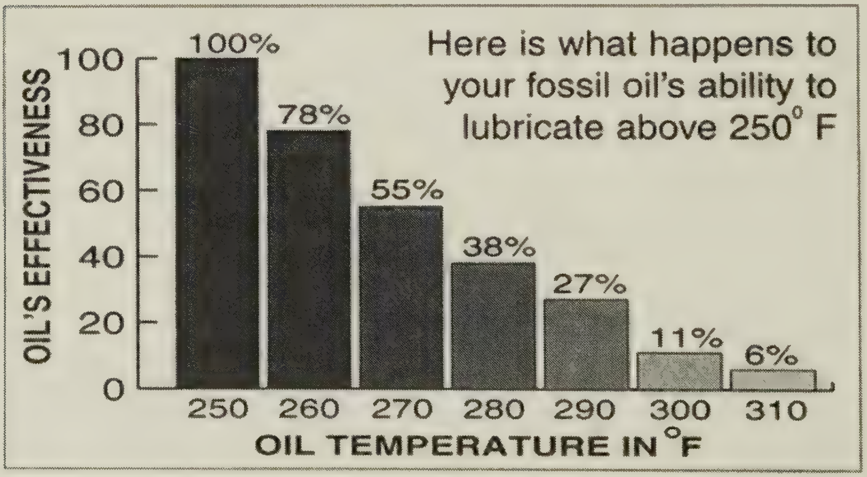
I have done this modification to my own Road Glide, and it provided a temporary, noticeable, and minor improvement. The bike still runs overly hot, though. It is a small fix for a much bigger heat discomfort problem. I still roast in the hot weather.

Oil Coolers

An oil cooler becomes prudent in hotter temperatures and may be required for a variety of other reasons. Normal operating temperatures for a Harley will rise if the motorcycle is lugged (low speed in a high gear), improperly tuned, on parade duty, or rush hour stop-and-go traffic, has air restrictions like leg shields, or is a stroked performance engine. There are a lot of things that can cause oil temperature to rise causing the problem of heat-oxidation.

When extreme overheating situations exist, oxidation is rampant. The only cure for oxidation is changing the oil. Extreme heat indicates the need to change your oil more frequently. There is no need to worry if the temperature rises above normal operating temperatures for a short period of time, but change the oil if you're in doubt. Observe manufacturers' recommended oil change mileage if normal temperatures are consistent but change more often when operating in severe conditions. Remember that unrestricted air flow is the other coolant that allows oil to disperse engine heat through the cooling fins. I explain oil coolers in great detail in Volume II: *Performancing the Twin Cam*: Chapter VI: *Oil Coolers* and will do so again in Volume IV: *Performancing the Evolution.*

As the chart indicates, the oil oxidation rate increases explosively above 250° F for fossil oil like that recommended by Harley. At 270° F, a mere 20° F above the 250° F limit, the oxidation rate doubles, thereby reducing the life of the oil by half. Sustained riding at over 300° F reduces oil life by 80%.



Reading the Oil Can

Oil used to come in cans but now, of course comes in plastic bottles. Like tires where all the information is molded into the sidewalks, oil containers have all the information needed to make an educated decision on whether it is appropriate for your motorcycle's needs. However, Harley-Davidson keeps its oil contents and ratings a big mystery. My opinion is that this is for marketing reasons of exclusivity.

API Oil Classification

Originally, oil was a simple product so a classification system was not required. As engines became more sophisticated and engineers constantly improved the qualities of oil a two-letter system evolved with the API beginning in 1952, which designates the service conditions under which the engine operates.

There are two basic categories:

S oils for spark ignition gasoline engines like Harley-Davidson.

1. C oils for compression-ignition diesel engines like the 18-wheelers.
2. However, S is not the acronym for gasoline although most of us refer to it as that. S is the acronym for Service. C is the acronym for Commercial. C oil was originally intended for commercial diesel engines. Now the two blend because there are many Service vehicles that use diesel engines and are not commercial.

An oil meeting API standards has a round white donut shaped logo split in two halves on the container. The upper half says API Service followed by two letters. S followed by another for a gas engine like Harley. If it is oil for a diesel engine the letter C will substitute for the S.

SAE Viscosity Ratings

Inside the API donut on the oil container label is the SAE (Society of Automotive Engineers) rating which indicates the oil's viscosity or ability to flow. The SAE rating may also appear elsewhere on the can or bottle. This numbering system identifies the thickness or more correctly, the viscosity of the oil. The larger the number will indicate the thicker or higher viscosity of the oil and vice versa. Technically, thickness is the wrong term although everyone seems to use and understand it. The ability of a fluid to flow defines viscosity. It describes fluid friction, which is a fluid's inner resistance to flow. For example, water has less intrinsic resistance to flow and is less viscous than honey, which has much internal resistance to flow and is thus more viscous. It is easy to see why the term and concept of thickness is applied. The measurement of viscosity by the SAE must have the constants of temperature, aperture size for flow-through, and smoothness of the flow-channel for particular oil's viscosity to relate to another.

SAE 70-wt. oil is thicker and will pour slower than a SAE 60 or SAE 50-wt. oil. Straight grade engine oil also thickens when sitting in cold weather causing resistance to the engine turning over while starting which also helps drain the battery. Dry starts because of oil's inability to flow until warmed up are a huge wear problem for the engine when using single viscosity oil. Hence the reasons for multi-viscosity oil like SAE 20W-50, which has the characteristics of SAE 20-wt. oil in cooler temperatures and the distinctiveness of SAE 50-wt. oil with hotter temperatures. After the engine heats up to full operating temperature, the oil thins, losing some of its film strength. Therefore, the 20-wt. viscosity will assist flow on crucial startup and the 50-wt. component will have the film strength and shear resistance of the heavier oil as temperatures rises. Another reason to use synthetics becomes evident since they flow more readily at lower temperatures lubricating parts sooner. Multi-grade oil has the advantages of both high and low viscosity oils.

- SAE 20W-50 is used in all Evolution and Twin Cam Harley-Davidson's giving the benefits of both cold situation 20-wt. oil and operating temperature SAE 50-wt. oil.
- Pre-Evos use SAE 40 for cold weather, SAE 50 for warm weather, and SAE 60 for hotter conditions.
- In early manuals when Harley was even seemingly more intent in confusing everyone, the Factory's designations were grade 58 (SAE 40); 75 (SAE 50), and 105 (SAE 60).
- Later manuals exacerbated this situation by designating their packaged product supplied by major refineries as special light (SAE 40), heavy (SAE 50), and extra heavy, which of course is the SAE 60-wt.

Except for Harley-Davidson and some aftermarket oil suppliers, almost every vehicle manufacturer in the world indicates the API, ILSAC and SAE ratings, as do the oil refiners and includes the designations on their containers.

What Does the W Stand For?

Many think the W in multi-viscosity nomenclature like SAE 20W-50 indicates weight, thickness or oil viscosity. The W indicates winter or cold use for the first numerals, in this case 20-viscosity.

ILSAC indicates Oil Quality

If there is a starburst by the API logo, it means that ILSAC (International Lubricant Standardization Approval Committee) standards have been met. This indicates that the oil has passed more stringent tests involving fuel efficiency and lower oil volatility (evaporation), which helps decrease oil consumption and benefits emissions systems. Flow properties, water tolerance, and the reduction of phosphorus in the lighter viscosity oils have also met higher standards. Increasing phosphorus levels increases oil lubricity, which is good. It also hurts catalytic converters, which I'm supposed to say is bad but as a Harley rider it doesn't really float my boat. This reduction of phosphorus is a major factor in the latest SJ oils, but does not affect 20W-50 oils since they are exempt.

SJ oil suitability may confuse many because phosphorus is indeed reduced in SAE 10W-30 oil for liquid cooled automobile use. However, its use is not restricted in SAE 20W-50 oil that has use for air-cooled engines like Harley-Davidson. *ILSAC rated oils may not be suitable for an air-cooled engine like Harley Davidson because of the possibility of phosphorus reduction.*

The Harley-Davidson Oil Refinery

Harley doesn't make its own oil. Of course, they don't, which is the norm for the vast majority of vehicle manufacturers. Harley-Davidson puts out tenders with the specifications it wants and the major oil refineries bid for the job. The winning product is packaged in Harley containers for the Motor Company. Quality and price are the overriding factors.

Discounting Discount Oil

The best quality fluids on the market should be used in the Twin Cam Harley-Davidson. Top-graded oil like API SH, or API SJ, or API SL is very much superior to discount oils that do not carry an SH, SJ, or SL API designation. This last statement used to be truer than it is now. Oil standardization is high with the majority of different oil brands on the market being very good. Read the container for API, SAE and sometimes ILSAC information to guide you the now educated consumer.

Do not take umbrage at my next statement. I believe that standard automotive additive packages are used in oil purportedly for motorcycle use only. I believe that the reason for motorcycle oil bases on two major points:

1. A vehicle manufacturer like Harley-Davidson wants to ensure consistent good product oil is used in their vehicles for both warranty reasons and customer satisfaction.
2. The development of for-motorcycle use only oil containers allows for higher prices and thus higher profits for essentially an automotive product.

Engine Oil Ratings

The reader might wonder why I digress into diesel engine oil ratings in this section. I do this because some diesel oils are temporarily suitable for use in the Twin Cam motorcycle if S-gasoline engine oil is unavailable.

When looking at an oil container for the API rating that is suitable for Harley-Davidson or any other vehicle for that matter, the consumer may see a dual Service/Commercial rating of SF/CC, which means:

1. SF is Service (gasoline) for 1980 to 1988 vehicles including Evolution Harley-Davidson. It supersedes with SG oil in 1989, SH in 1994, and SJ in 1997 for the remainder of the Evolution and into the early Twin Cam years with SL introducing in 2002 and suitable for all Twin Cams.
2. CC is Commercial (diesel) oil introduced in 1961 and is suitable for 1961 to 1986 vehicles. It supersedes with CE oil in 1987, CF-4 in 1990, and a CG-4 in 1994 for the remainder of the Evolution and into the early Twin Cam years. CI-4 oil introduces in 2002 and is suitable for all Twin Cams.

S-gasoline Engine Oil Ratings

For liquid cooled gasoline engines, the most recent engine API category will include all of the properties of all earlier categories. The question becomes, if an automotive owner's manual calls for API SJ or SL oil, if API rated SM oil will provide full protection for a liquid-cooled car. *I do not recommend using an SM rated oil in an air-cooled motorcycle.* However SJ and SL oils are available and will provide full protection and lubricity in a Twin Cam air-cooled motorcycle.

API	2010 Status	Introduction	Characteristics
S	-	-	Suitable for gasoline engines
SA	Straight Petroleum	-	Unsuitable for Harley-Davidson
SB	Superseded	1933 to 1963	Unsuitable for 1963 and later
SC	Superseded	1964 to 1967	Unsuitable for 1967 and later
SD	Superseded	1968 to 1971	Unsuitable for 1971 and later
SE	Superseded	1972 to 1979	Unsuitable for 1980 and later
SF	Superseded	1980 to 1988	Unavailable but suitable for Evolution
SG	Superseded	1989 to 1993	Unavailable but suitable for Evolution
SH	Superseded	1993 to 1996	Unavailable but suitable for Twin Cam
SJ	Current	1997 to 2001	Available and suitable for Twin Cam
SL	Current	2002 to 2004	Available and suitable for Twin Cam
SM	Current	2005 to present	Do not use in an Evo or Twin Cam!

If a dual set of letters appear such as SJ/CF, the oil may be used for both gasoline and diesel engines.

C-diesel Engine Oil Ratings

The C-series of oil are for diesel engines. They will safely substitute for Harley-Davidson engines if S-type gasoline oil is unavailable. Unlike the S-series gasoline oils, the diesel oil in the latest category will usually but not always include all of the properties of all earlier categories. It is safe to use CF-4, CG-4, and CH-4 or CI-4 diesel oil in a Harley-Davidson. I do not recommend using CJ-4 diesel engine oil in an air-cooled motorcycle like the Evolution or the Twin Cam. These various diesel oil classifications will retrofit back to 1984 and beyond. Change back to an S gasoline engine oil at the earliest convenience.

API	2010 Status	Introduction	Suitable for diesel engines
C	Obsolete	1940 to 1960 (light)	Unsuitable for current engines
CB	Obsolete	1949 to 1960 (moderate)	Unsuitable for current engines
CC	Obsolete	Introduced in 1961	Unsuitable for current engines
CD	Obsolete	Introduced in 1955	Specialty oil; unsuitable
CD-II	Obsolete	1987 to 1993	2-stroke oil which is unsuitable for Harley-Davidson
CE	Obsolete	1987 to 1990	Use in place of CC, CD
CF	Current [1]	1994 to present	Unsuitable for Harley-Davidson
CF-2	Current	1994 to present	2-stroke oil which is unsuitable for Harley-Davidson
CF-4 [4]	Current [2]	1990 to 1994	Use in place of CD, CE
CG-4 [4]	Current [3]	1995 to 2001	Use in place of CD, CE, CF-4
CH-4 [4]	Current [3]	1998 to 2002	Use in place of CD, CE, CF-4, CG-4
CI-4 [4]	Current [3]	Sept. 5, 2002	Use in place of CD, CE, CF-4, CG-4, CH-4
CJ-4	Current	present	Unsuitable for Harley-Davidson (my opinion)

[1] CF diesel oil is primarily for off-road use. It is for fuels with over .5% by weight sulphur.

[2] CF-4 diesel oil has use for both naturally aspirated (carburetor or EFI) and forced induction, which in this case is turbocharging.

[3] These C-oils are designed to use with diesel fuels with a sulphur content of less than .5% by weight. Sulphur is the pollutant responsible for acid rain. CI-4 oil is designed for use with turbocharged engines as well as naturally aspirated ones like the Twin Cam.

[4] If gasoline engine oil is not available, it is safe and advisable to use the following diesel oil; CF-4, CG-4, CH-4 or CI-4, which is also suitable for gasoline S engines.

There are only three API classified oils currently available for automobiles and motorcycles, which are SJ, SL, and SM. Up until the advent of SJ oil in 1997, the previous classified automotive oils were excellent oils for the Harley-Davidsons of the day. Liquid cooling and energy conservation methodologies have raised concerns on whether modern motor oils, specifically current SL and SM oils in 2010 are suitable for the Evolution and Twin Cam motorcycles. The worry they pose for use in Harley-Davidson air-cooled engines are the amount and combination of the anti-wear agents zinc (Zn) and phosphorus (P) that make up the additive ZDDP (zinc dialkyl dithiosphosphate). This is also a question for air-cooled automotive engines using SJ 10W-30 oils. However, the changes were exempted from the SJ SAE 20W-50 oil that is suitable for Harley-Davidson use. I will expand on the SJ oil further on in this chapter.

What about SI or SK oils? They don't exist since API chose not to use I or K nomenclature.

Air-cooled engines require the following characteristics in suitable oil:

1. Maintain adequate lubrication.
2. Maintain film strength under high pressure conditions like those found with roller cam followers (tappets).
3. Thermally stable with high temperature operation.
4. High flashpoint because of higher temperatures.
5. Low Noack volatility where oil is able to resist evaporation because of consistency of molecular size.

However, the danger for an air-cooled engine is that some modern oil is reformulated to provide for a decrease in emissions and to allow longer drain intervals. Reformulation may decrease the amount of ZDDP in the oil, which is a superb anti-wear and anti-oxidant additive package. Oil's effectiveness whether it is H-D 240 or H-D 360 oil or any other fossil oil may be limited in its performance capability because of recent limiting factors imposed by environmental considerations. In other words, within reason the environmental emissions controls take precedence over the optimal functioning capability of modern oil lubrication and engine protection.

Do Not Switch Oil Brands Indiscriminately

1. Do not add fossil oil to synthetic oil. However, if changing from one to the other, it is safe to do so with a full oil change.
2. Do not add synthetic oil to fossil oil. However, if changing from one to the other, it is safe to do so with a full oil change. I run fossil oil for the first 1500 miles on a new engine and synthetic thereafter.
3. Switching oil brands all the time is not a good idea since additive packages or chemicals in one engine oil may adversely chemically react with those in different brand oil. This does not mean that a rider cannot change brands. It does mean not to do it every oil change.
4. If SAE 20W-50 is not available use 15W-40. Change oil back to SAE 20W-50 at the earliest convenience. Use 10W-40 in an emergency only since any oil is better than no oil. Change oil back to a good quality SAE 20W-50 oil as soon as possible.
5. If gasoline engine oil is not available, it is safe and advisable to use the following diesel oil; CF-4, CG-4, CH-4 or CI-4, which is also suitable for gasoline S engines.

Harley-Davidson Oil Specifications

Engine	**Pre-1978**		
Early Shovel	SAE	H-D rating	Temperature
Special Light	40	58	Below 40° F (4° C)
Medium Heavy	50	75	40° F to 90° F (4° C to 32° C)
Regular Heavy	60	105	Above 90° F (32° C)
Late Shovel	**1978 to 1983**		
Special Light	40	Premium II	-20° F to 40° F (-29° to C4° C)
Medium Heavy	50	Premium II	40° F to 60° F (4° C to 16° C)
Regular Heavy	60	Premium II	60° F to 80° F (16° C to 27° C)
Extra Heavy 60	60	Premium II	Above 80° F (27° C)
Super Premium	20W-50	Power Blend	10° F to 100° F (-12° C to 38° C)
Evolution	**1984 to circa-1998**		
Multigrade	10W-40	240	Below 40° F (4° C)
Multigrade	20W-50	240	20° F to 100° F (-7° C to 38° C)
Regular Heavy	50	240	60° F to 100° F (16° C to 38° C)
Extra Heavy	60	240	80° F to 100° F (27° C to 38° C)
Twin Cam/Evo	**Twin Cam + Circa-1999 to 2000 Evolution**		
Multigrade	10W-40	360	Below 40° F (4° C)
Multigrade	20W-50	360	Above 40° F (4° C)
Regular Heavy	50	360	Above 60° F (16° C)
Extra Heavy	60	360	Above 80° F (27° C)

The work on developing Harley-Davidson H-D 240 oil originally began because engineers were looking for a solution to sticking valves in late Shovelhead engines. The cause seemed to defy reasoning to the engineers. If I may be so bold, a material change to say Ampco-45 bronze for the valve guides solved the problem for me. Extending valve guide length also resolved oil blow-by past the guides.

1. An engine will run cooler and use less oil if the oil tank is kept full.
2. SAE 20W-50 is good oil for cold weather starting. Cold weather starts define as below 50° F. The person who came up with this figure must be from the Southwest USA because this temperature is still warm in Toronto, where I live.
3. Multigrade oil characteristics are achieved by the addition of polymers in the additive pack. The Power Blend multi-viscosity oil gave much better protection than the Premium II and earlier straight grade H-D oil.
4. Power Blend oil is the first H-D oil specified by Harley-Davidson engineers through their own extensive testing. Power Blend was available in SAE 20W-50 and recommended for all temperatures, SAE 50 (60° F to 100° F/16° C to 38° C), and SAE 60 (80° F to 100° F/27° C to 38° C).
5. SAE 50 has poor cold weather starting attributes.
6. SAE 60 has further reduced cold weather starting attributes.

Evolution and Twin Cam Oil Quantity Specifications

Engine Oil [1]	**U.S.**	**Metric**	**Check oil**
FLT 1984-1992	4 quarts	3.78 liters	Upright
FLT 1993-1998 [2]	4 quarts	3.78 liters	Sidestand
FLT 1999-to-present [3]	3.5 quarts	3.3 liters	Sidestand
FXR 1982-1994/99-2000	3 quarts	2.80 liters	Sidestand
Dyna 1991 to 1998	3 quarts	2.80 liters	Sidestand
Dyna 1999-to-present [4]	2.5 quarts	2.4 liters	Sidestand
1984 to 1999 Softail	3.0 quarts	2.8 liters	Upright
2000-to-present Softail	3.5 quarts	3.3 liters	Upright
Primary Oil [6 7]			
1984 to 1989 all	1.5 quarts	1.42 liters	Upright
1990 to 1997 FLT	38oz to 44oz	1125ml to 1300ml	Upright
1998 FLT	32oz	946ml	Upright
1999-2005 FLT	32oz	946ml	Upright
2006-to-present FLT [8]	38oz	1124ml [9]	Upright
1990 to 1994 FXR	38oz to 44oz	1125ml to 1300ml	Upright
1999 to 2000 FXR	32oz	946ml	Upright
1991 to 1997 Dyna	30oz to 36oz	887ml to 1065ml	Upright
1998 Dyna	26oz	769ml	Upright
1999 to 2005 Dyna	26oz	.769ml	Upright
2006-to-present Dyna [10]	32oz	0.946 liter	Upright
1990 to 1997 Softail	30oz to 36oz	887ml to 1065ml	Upright
1998 to 1999 Softail	26oz	769ml	Upright
2000 to 2005 Softail	26oz	769ml	Upright
2006-to-present Softail	32oz	0.946 liter	Upright
Transmission [11]			
1984 to 1990 FLT	1 pint (16oz)	473ml	Upright
1991 to 1997 FLT	20oz to 24oz	590ml to 710ml	Upright
1998 FLT	20oz to 24oz	590ml to 710ml	Upright
1999-2005 FLT	20oz to 24oz	590ml to 710ml	Upright
L-2005-to-present FLT	32oz	946ml	Sidestand
1984 to 1990 FXR	1 pint (16oz)	473ml	Upright
1991 to 1994 FXR	20oz to 24oz	590ml to 710ml	Upright
1999 to 2000 FXR	20oz to 24oz	590ml to 710ml	Upright
1991 to 1994 Dyna	1 pint (16oz)	473ml	Upright
1995 to 1998 Dyna	20oz to 22oz	590ml to 650ml	Upright

1999-2005 Dyna	24oz	710ml	Upright
2006-to-present Dyna	32oz	0.95 liters	Sidestand
1984-1985 Softail	1.5 pints	710ml	Upright
1986-1990 Softail	1.0 pint	473ml	Upright
1991-1999 Softail	1.25 to 1.50 pints	590ml to 710ml	Upright
2000 to 2005 Softail	20oz to 24oz	591.5ml to 709.8ml	Upright
2006-to-present Softail	32oz	0.946 liters	Sidestand

The rear chain case on early enclosed rear chain drive FLT models requires 6oz (177ml) of oil for rear chain lubrication.

Getting the proper fill requirement can be difficult:

1. I hate to say this but different workshop manuals and owner's manuals sometimes give conflicting information for oil-fill specifications.
2. Sometimes, mechanics are not well-versed in the changing methodologies (sidestand or upright) for measuring fluids.
3. To compound these problems, there are also *wet* and *dry* specifications especially for primary chaincase and transmission applications. Wet simply means that the oil has been drained without disassembly or cleaning. Wet measurements will always be less than a dry specification. Dry measurement is required if the clutch has been disassembled and cleaned or the transmission housing has been removed and wiped dry.

[1] Check manual for your year and model for full oil tank specifications. This is very important as specifications change from one year to another and one model to another. I describe cold oil checks and the more accurate and preferable hot oil checks for Twin Cams elsewhere in this chapter. Overfilling an oil tank will remove air space at the top necessary for venting. Overfilling will invariably lead to oil leaks and/or oil blowby out the engine breather venting system into the air cleaner. As an example, the Evolution oil tank is full when the oil is at the upper level on the oil dipstick. In order to properly read the dipstick, the engine must be run for at least 10-minutes in order for the engine to reach operating temperature. Then allow the oil to settle in the oil tank for a few minutes before checking the dipstick. This is important as oil quantity requirements vary for different models, as does the checking procedure. The rubber on the oil filter should receive a light coating of engine oil for sealing purposes. Snug the oil filter onto its attachment. Tighten ¼ turn to ½ turn thereafter.

[2] FLT/FLHT oil tanks were redesigned for 1993 to present. The tank moves from above the transmission to underneath and attached to the transmission base. FLHTC, FLTC-U, FLHTC-U (62489-93) and the FLHR (62490-93) made the change in 1993 while the FLHS (62489-93) did so in 1994. The Dyna was the first to make this oil reservoir (26074-90) move in 1991. The advantages are a lower center of gravity for better handling, improved oil cooling, and transmission noise reduction for the EPA. The oil should now be checked with the bike on the sidestand at normal operating temperatures after being allowed to settle for a few minutes. Clean oil plug with a rag, insert completely into the transmission oil pan, remove and read the dipstick. The oil pan incorporates both engine and transmission oil plugs. The front one is for the engine oil in the oil pan while the rear one is for the transmission fluid. The oil in each remains separate. The oil lines are preformed so we mechanics cannot screw up the routing, kink them or place them in harm's way. Finally, the frame cross member is inverted for oil reservoir clearance as are all FLT replacement frames from 1993-on. The foregoing is

generalized information; again, check your specific manual for year and model as checks and fill requirements can change dramatically.

[3] An accurate oil level cannot be checked on a cold engine. However, if doing this, the oil level should be between the two arrows on the oil dipstick. A hot check is accurate and should be performed when the oil is at normal operating temperatures. After proper temperature is achieved, let the engine idle for a few minutes on the sidestand. Turn the engine off; remove dipstick; wipe off oil residue and re-insert with the cap fully screwed into the oil spout. Remove, once again; oil should be at the top arrow, which is full hot level.

[4] Twin Cam Dyna Glides have wet fill and dry fill specifications. The wet fill specification is shown in the chart for a normal oil change where the oil pan has been drained but not removed. Wet fill requires less oil because residue cling oil remains in the oil pan. If the oil pan has been removed and cleaned for whatever reason including an engine rebuild it is considered dry. Dry fill specification is 3.0 quarts (2.7 liters).

[5] A sidecar equipped bike is obviously upright on level ground. Check the opposite side of the dipstick, which has two diamonds imprinted on it. The inaccurate cold check is in the center of the two diamonds while the hot check, which is performed as above, is at the top diamond. In either scenario with a 2-wheeled or 3-wheeled motorcycle if oil needs to be replenished, only add enough oil to the demarcation points described. *Do not add oil on a cold engine to the full mark!*

[6] Some 1984 and 1985 Evolutions notably FXST and carryover FX models ran dry clutches without primary fluid. H-D part number for primary chaincase lubricant is H-D 99892-84.

[7] Important! Do not overfill the primary chaincase with fluid. This may cause rough clutch action (engagement and partial disengagement), dragging clutch and difficulty in finding neutral.

[8] Wet specification calls for 38oz (1124ml). If dry use 45oz (1331ml). Wet fill occurs when primary cover is not removed and old fluid drains via the plug. Residue oil remains inside necessitating a smaller amount of fresh fluid fill. Dry fill requires more fluid because the primary cover is removed during service. Old fluid will drain more thoroughly plus cleaning will remove cling fluid thus necessitating a higher fill specification.

[9] Be careful with conversion values in manuals and charts. They may not be accurate. For example I have seen U.S. 38oz listed as 1124ml in one authorized manual and 1177ml in another. I did the mathematics myself finding 1124ml to be the correct conversion. While the discrepancy in this case is not great it will lead to overfilling, which in a primary chaincase will lead to a grabby clutch and shifting into neutral difficult. In a transmission, venting may compromise or oil may be forced out a weak seal.

[10] If cleaning old clutch plates or installing new ones, submerge the plates in primary fluid for about five-to-ten minutes before reinstallation. This will replace cling and absorbed oil that would normally remain with the clutch pack.

[11] Check transmission when cold or after oil has settled for a few minutes when hot. Harley transmission lubricant is H-D 99887-84 for 1984 to 2005 Evolutions and early Twin Cams. Twin Cams from late-2005-to-present use H-D 99851-05 that doubles as a primary lubricant for these years.

Primary and Transmission Lubricants

1. The 1984 to 2000 Evolution and Twin Cam 1999 to 2005 use PRIMARY CHAINCASE LUBRICANT H-D 99887-84. These years use 32 ounces (946ml) in FLT touring models (check manual for year and model for recommended fill rate). Primary fluid should be changed at the first new motorcycle service and every 5000 miles (8000 kilometers) thereafter. I believe that the primary oil is SAE 10W-40 oil with a red dye.
2. I recommend one of many excellent oils, Mobil 1 MX4T 10W-40 for the primary 1984-to-present and 80/90 semi-synthetic Hypoid gear oil for the transmission. I do not believe in running the same fluid in the Big Twin primary chaincase and transmission. However, to be forthright, I must report that the Sportster has used the same fluid in both primary and transmission forever without negative results that I am aware of.
3. Twin Cams from late-2005-to-present use 38 ounces (1124ml) wet and 45 ounces (1331ml) dry, which means the primary cover was removed for service in FLT touring models (check manual for year and model for recommended fill rate) of FORMULA+ TRANSMISSION AND PRIMARY CHAINCASE LUBRICANT H-D 99851-05. Interval changes increase from the 1000 mile (1600km) and every 10,000 miles (16,000km) thereafter.
4. The 1984 to 2000 Evolution and 1999 to 2005 Twin Cam transmission lubricant is H-D 99892-84. It should be changed after 2500 miles (4000 kilometers) and every 5000 miles (8000 kilometers) thereafter. I believe that H-D transmission oil is semi-synthetic 80/90 hypoid oil.

Hypoid Gear Oil

Hypoid actually refers to a set of specialized off-axis gears that require a fluid called hypoid oil that can withstand extreme pressure between the mating teeth. The reader has probably seen examples or pictures of these gears in a car differential housing where the angled and slanted gear teeth taper down and intersect with each other at a 90^0 or close to this pitch. Harley-Davidson transmissions, whether fitted with traditional straight cut or the later helical gears are not hypoid as the gears meet each other straight-on (180^0). However, both types of gears have high pressure contact as the mating straight cut gears are ground for a high contact ratio and the mating helical gears are in constant contact with much side thrust. Transmission oil should have shear resistant molecules to prevent them from being easily chopped up by gear teeth interaction.

Gear oil is a motor oil made specifically for transmissions, It is of a higher viscosity to better protect the gears and usually is associated with a sulfur anti-wear additive that may smell. As I have said at 100^0 C (212^0 F) gear oil viscosity ratings equal that of multi-grade motor oil (80/90 gear oil equals 20W50 oil viscosity at this high temperature whereas 75/90 gear oil is equivalent to a 10W40 engine oil viscosity). However, H-D transmissions do not achieve this high temperature so the gear oil is effectively a higher viscosity under most actual operating conditions.

The high viscosity ensures transfer of lubricant with superior cling properties throughout the gear train in this wet sump situation. Only a portion of the lowermost gear sections are bathed in the H-D transmission wet oil sump. A wet sump means that there is no remote oil tank to store the oil. The transmission casing is the reservoir for wet sump oiling. In contrast, the Harley engine uses a dry sump system where a remote oil tank supplies pumped oil to the engine and a return pump to the oil tank.

Most lubricants for manual gearboxes are hypoid gear oils. These contain extreme pressure (EP) additives and anti-wear additives to cope with the high pressure of mating gear teeth contact.

Twin Cam Oil Pressure

TC88, TC96, TC103, and CVO 110 Twin Cam oil pressure should range between 30psi to 38psi (207kN/m^2 to 262kN/m^2) at 2000 rpm/engine at operating temperatures, which is 230° F (110° C).

Compare this with the Evolution range of 12psi to 35psi (83kN/m^2 to 241kN/m^2) @ 2000 rpm/engine at operating temperatures.

Fluid Equivalents

	Fluid Ounces	Pint	Quart	Gallon
USA	16	Equals 1	Equals .5	Equals .125
Imperial	20	Equals 1	Equals .5	Equals .125

USA	Imperial	Metric
1 fluid ounce	Equals 1.042oz	Equals 29.574ml
1 Pint	Equals .833oz	Equals .473 liters
1 Quart	Equals .833 quarts	Equals .946 liters
1 Gallon	Equals .833 gallons	Equals 3.875 liters

Confusing for sure; there are three main fluid measurements (USA, British Imperial, and Metric) with some different ones bearing the same name. It is important to state whether pints, quarts, and gallons are USA or British Imperial. For example, both USA and Imperial have 4-quarts to the gallon. However, the volumes of both differ. Be careful with conversion values in manuals and charts. They may not be accurate. For example I have seen U.S. 38oz listed correctly as 1124ml in one authorized manual and 1177ml incorrectly in another (2007 HARLEY-DAVIDSON® INTERNATIONAL OWNER'S MANUAL, H-D 99466-071, page E62). While the discrepancy in this case is not great it will lead to overfilling, which in a primary chaincase will lead to a grabby clutch and shifting into neutral difficult. In a transmission, venting may compromise or oil may be forced out a weak seal.

API SJ Oil Suitability for a Twin Cam Air-cooled Motorcycle

The following information also applies to Evolution motorcycles. In 1997, API SJ oil superseded API SH oil, which most will acknowledge is an excellent oil for Harley-Davidson usage. Many Factory dealers began to say that API SJ oil was no longer safe to run in a Harley-Davidson. The rationale was that it was designed for a water-cooled engine while Harley is obviously air-cooled. How this engineering works is that water-cooled engines now use different additive packages that reduce necessary anti-wear agents for an air-cooled engine like Harley-Davidson.

It is true that API SJ lower viscosity oil's like SAE 10W-30 are no longer suitable for air-cooled engines because:

1. Reduction in certain anti-wear additives, which is okay for lower temperature water-cooling but not higher temperature air-cooling.
2. Low viscosity.

However, API SJ SAE 20W-50 oil is exempted from this anti-wear additive reduction policy. This is why API SJ SAE 20W-50 oil is excellent oil for the Evolution and Twin Cam motorcycle because:

1. Anti-wear additives are not reduced.
2. The viscosity is correct.
3. The full additive package is excellent for an air-cooled engine.

Water cooled engines like the V-Rod are more efficient because operating temperatures are controlled by the constant cooling fluids that dissipate their heat through a radiator no matter the operating conditions. Water-cooled engines typically operate at less than 200^0 F while a Harley is over 220^0 F. This information can lead to inappropriate conclusions, logical as they may seem.

However, it is the quality of the oil viscosity that determines whether it is going to break down with heat and at what temperature. Any SJ 20W-50 oil is just as capable of handling air-cooled engines as an SH one. Modern marketing can be very skilful in making the consumer paranoid about using anything but the manufacturer's suggested oil. One thing is for sure though; the development of oils is undergoing radical development because of environmental concerns.

The Silent War between Manufacturers

There is a war going on out there that you the consumer don't hear about. It's between major vehicle producers and the oil companies. The reason for this ongoing dispute is complying with ever-stringent emissions controls. I realize I go on about this a lot but if you think about it, the way your Harley or any other vehicle is going to look or be built is totally dependent on the amount of allowable noise and exhaust pollution in the future in conjunction with better mileage attributes. So, what's the fight about? Well, the vehicle manufacturers want the oil companies to develop costly formulation changes in the oil and gasoline to reduce emissions so that the manufacturers don't have to make as many expensive design changes to improve fuel economy and emissions controls. For example one big fight is the amount of sulfur in gas. The manufacturers want the oil companies to reduce the content so the acid rain causing pollutants are reduced helping the vehicle people meet their government guidelines.

The Law on Voiding Warranty

The following two questions involve a common intentional and in some cases unintentional scare tactic to force or coerce customer loyalty.

1. Can a manufacturer void their motorcycle warranty unless their oil, oil filter, or air filter is used?
2. Furthermore, does an authorized dealer have to install the oil, oil filter, or air filter for warranty reasons?
3. The United States passed the Magnuson-Moss Warranty Act in 1975 whose statute governs warranties on consumer products. Named after its sponsors, United States Senator Magnuson and Senator Moss, most other western countries have followed suit with variations of this consumer protection law. According to the Report of the House of Representatives, which accompanied the law, Congress enacted the Magnuson-Moss Act in response to the widespread misuse by merchants of express

> warranties and disclaimers. The legislative history indicates that the purpose of the Act was to make warranties on consumer products more readily understood and enforceable and to provide the Federal Trade Commission with means to improve protection of consumers. [1]

There is no law to force manufacturers to give a warranty on consumer products. However, if a warranty is given, which Harley-Davidson obviously does, it must comply with the Magnuson-Moss Warranty Act. This law states in part that it is against the law for a vehicle manufacturer to mandate the use of a specific air filter, oil filter or oil unless it provides these items *free of charge*.

The manufacturer, however, can insist on adhering to their specifications with aftermarket replacements of filters and/or oil, which is fair. When I first started wrenching in the late sixties, I think replacement quality was a concern. There were filters, whether it was an air or an oil filter, that were substandard and the same concern applied to oil.

I think brand name air/oil filters and oil are all of superb quality these days. A few years ago at *American Iron Magazine*, we tested numerous oils, both fossil and synthetic to find out the best one for a Harley-Davidson. They were all excellent including the H-D proprietary oils. Some were better than others were but only by small degrees, any would do your bike proud and none tested would cause harm. There is a host of aftermarket specialty performance oil and air filters along with oil itself that are of the highest quality.

Oil Recommendations for the Twin Cam

The following information also applies to Evolution motorcycles. I recommend the use of fossil oil for a break-in period for a new engine for the first 1500 miles (2400 kilometers). I then recommend the discontinuance of fossil oil in favor of synthetic oil for the rest of the life of the engine. The time is approaching when synthetic oil will also be appropriate during break-in because of improved metallurgy, machining, and the use of protective slippier coatings on moving parts like Teflon coated piston skirts and copper-coated bearing cages. The use of synthetics in new engines will probably coincide with liquid cooling for all Harley-Davidson motorcycles. Air-cooled special need engines like the Twin Cam will become a thing of the past.

I also feel a turbulated oil cooler is appropriate and will help protect the engine from the ravages of heat-induced oxidation. Turbulation mixes the oil as it flows through the cooler so that maximum heat can dissipate (heat rejection) into the air. My first choice is 10-row Jagg oil cooler because of less oil restriction followed closely by a new Harley-Davidson turbulated cooler retrofitting back to the Evolution. The maximum number of rows or channels on these coolers is the better choice. Original Harley-Davidson oil coolers made by Lockhart (Shovelhead Sturgis models) are not turbulated and while better than nothing, turbulation gives maximum relief. In climates with normal summer temperatures an oil cooler is a nice adjunct particularly for August temperatures but becomes very necessary for hotter climates like the USA Midwest and South.

Harley-Davidson Products

I recommend H-D 360 oil for the Twin Cam. I recommend both the H-D 240 and H-D 360 oil for the Evolution motorcycle. Both are excellent fossil oils. Syn 3 is good synthetic oil as most are although I personally would only use it in the engine and not the transmission or the primary chaincase. If the reader decides to use it in all three applications, no harm will result. You know what? I am having trouble saying that last statement. I am now getting reports in 2009 of Twin Cam transmissions having problems because of the use of Syn 3 oil. I cannot yet conclusively say this is the true cause but it makes me uncomfortable.

Automotive Oils

I believe that top grade brand name SJ or SL SAE 20W-50 automotive fossil oils are excellent inexpensive alternatives for the Evolution and Twin Cam. These are the oils, I use whether for break-in or for the life of the engine.

The specific automotive grade oil I recommend is SAE 20W-50 SJ automotive oil as perfectly safe for both Twin Cam and Evolution Harley-Davidsons. While I prefer SJ automotive oil over SL automotive oil, I believe SL SAE 20W-50 engine oil as a viable and safe alternative for 1984-to-present motorcycles.

My favorite automotive synthetic oil for the Evolution or Twin Cam for that matter is Mobil I: 15W-50. Even though the lower winter viscosity is 15-weight and not the usual 20-weight, I believe this to be the best oil amongst many great oils. The majority of automotive synthetic oils are excellent for the Twin Cam and the Evolution.

The Mobil I: SAE 20W-50 specific motorcycle oil is more expensive. I have nothing but good to say about this oil except the extra expense. I personally believe Mobil I is cashing in on the H-D niche marketplace with the Harley boom with its motorcycle synthetic. Be that as it may, it still ranks at the top with Mobil I automotive oil.

Aftermarket Automotive Oils

Dare I leave one of these excellent oils out of the discussion? I do not have bad to say about any of them whether fossil or synthetic *especially of the ones that cater to an air-cooled engine.* Amsoil, Spectro, Belray and a host of others are favorites of many Harley riders and I concur.

What oil do I use? Kendall GT1 from Pennsylvania has always been a favorite fossil oil as is any top of the line API SG, SH, SJ or SL 20W-50 oil from this State. It turns out with the 10-oils *American Iron Magazine* and I had analyzed that Kendall had more anti-wear additives than Harley's 360 and it is car oil.

Other fossil oils like CCI's Rev Tech, Bikers Choice Twin Power, Silkolene, and of course Harley are all excellent oils for your Harley-Davidson and will provide excellent service. I have left out many excellent oil brands for the Twin Cam and Evolution motorcycle. However, I have given the reader the analytic criteria for determining their worth for the late model Big Twins.

You know, I just tried to think of bad premium oil for an air-cooled Harley-Davidson and I cannot think of any. Of course, the exceptions are oils I have already mentioned like mineral oil that is base stock without additive packages; air-cooled airplane oil's because they lack necessary additives like a detergent for a Harley and some API-SM and later modern oils for liquid-cooled engines and catalytic converters because of a reduction in anti-wear additives so necessary to an air-cooled engine. I will pursue this in more detail in the following section as it bears repeating.

For synthetics, the automotive Mobil 1 15W-50 was tops in our analysis group including specific synthetic oil's formulated for Harley-Davidson. Mobil 1 held top place for the least breakdown in viscosity, (oxidation), of any of the oils we tested. This viscosity retention analysis is very important in choosing oil for your machine. Mobil 1 officials expressed surprise since they do not target the motorcycle industry at all with their automotive oil but then of course knew they had a top quality product.

I Do Not recommend the following Oil for the Twin Cam or Evolution Engine

I do not recommend SM or CJ-4 oil or subsequent new designations as they become available for an *air-cooled* Harley-Davidson not because it has been proven bad but because not enough is known about its long term effects.

However, a growing concern for the air-cooled crowd is the use of Calcium (Ca) detergent in combination with the anti-wear agents of zinc and phosphorus. Calcium causes more wear than other chemical detergents such as calcium/magnesium (Ca/Mg) or calcium/magnesium/sodium (Ca/Mg/Na). There is a trend in modern oils as I write this in 2010 that the oil industry is moving towards a reduction in the use of zinc and phosphorus anti-wear additives, which we need for air-cooled engines. Furthermore, an industry trend is moving towards calcium-based detergents. Oil companies are beginning to use zinc-free (ZF) anti-wear additives in conjunction with ash-free dispersants (detergents) in what is called SAPS (Sulphated Ash, Phosphorus, and Sulphur) oils. The reason is that zinc, phosphorus and sulfated-ash are injurious to catalytic converters. Therefore, this whole move once again demonstrates that modern engine oils must bend to the dictates of the EPA and CARB. They must find ways to provide oil's functional necessities with the added burden of complying with environmental laws. The expensive anti-wear agent Molybdenum (Mo) is used in many friction modifiers and works well in air-cooled engines.

SAPS oils use zinc-free anti-wear-dispersants like Boron (B), which will not interfere with catalytic converters or new automotive particulate-emissions-filters. This is necessary because the EPA wants the emission control warranties to extend. EPA also wants ongoing improvements in fuel economy, which partially evolves from less friction in the engine.

One way is to use lower viscosity oils in the engine since higher viscosity oil like SAE 20W-50 creates *drag* with high viscous friction. Water-cooling in future H-D engines will allow use of lower viscosity oils.

1. However, lower viscosity oil reduces:
    a) Oil film strength necessary to separate mating parts in pressure situations like roller tappets on cam lobes.
    b) The ability to deal with both high temperature oxidation and shearing or chopping up oil molecules.
    c) Air-cooled engines like the Harley-Davidson Twin Cam and Evolution are very dependent on oil film strength and are susceptible to high temperature oxidation and molecular shearing. Harley-Davidson riders should *avoid* the use of engine oil that:
2. Meet *Energy Conserving I* or *Energy Conserving II* standards. These classifications are clearly marked on oil containers.
3. API SM oil classification.
4. ILSAC GF-4 classification.

In short, modern 2010 oil will not retrofit back to Evolution or service Twin Cam air-cooled engines unless especially formulated for this use, which means it will have an API SH or API SJ or API SL rating.

Oil Pressure

TC88, TC96, TC103, and CVO 110 Twin Cam oil pressure should range between 30psi to 38psi (207kN/m^2 to 262kN/m^2) at 2000 rpm at engine at operating temperatures, which is 230° F (110° C). Compare this with the Evolution range of 12psi to 35psi (83kN/m^2 to 241kN/m^2) @ 2000 rpm/engine at operating temperatures.

Oil pressure will generally increase above this range on first starting a cold engine and settle down to within this range when warm. This is another reason synthetic oils are superior as they will flow easier and faster in a cold engine protecting moving parts from oil-starvation. Many engines will have a reading of less oil pressure when hot. Do not automatically assume the oil pump deficient and at fault. It may well, be the measuring tool or the oil pump gauge giving a false reading. Oil pump gauges can be notoriously inaccurate.

Oil pressure determines by the close proximity of the gears to their housing surroundings in Evolution and predecessor engines. If the housings wear, oil pressure will decrease. Usually dirt, grit or worn metal filings will flow into either the feed or return depending on routing and mesh between the hardened steel gears or geroters as the case may be. The gears/geroters rarely damage relative to their soft surrounding aluminum alloy housing. However, make no mistake a filing between gear teeth or geroters can damage them also. A piece of grit will usually travel around scraping or cutting a pathway on the alloy pump surface.

Prior to circa 1967, oil pumps were manufactured from cast steel with the same types of meshing gears. These steel oil pumps were not as precise as the later aluminum ones but more sturdy. They did not generate the same feed or return pressures. The advent of the aluminum oil pump brought the necessity of cleaner oil and thus superior oil cleansing via the oil filter.

The Twin Cam depends on internal oil pump geroters that cover oil intake and oil out-take ports while putting trapped oil in a decreasing-size space to create higher volume and higher pressure than the moderate volume and moderate pressure of a gear-driven pump. Greater pressure is created because oil will not compress like say, air will.

Superior oil filtration from a 1999 to 2006 10-micron filter and the 2007-to-present 5-micron filter ably protect the alloy oil pump housing from damage due to particulate in the traveling oil.

Oil Pressure Problems

Low oil pressure may be symptomatic of a number of situations.

The obvious one that many forget to check is whether the oil pan or oil tank is under-filled. Lower oil reservoir levels than specified will also cause a rise in oil temperature, which increases the ravages of oxidation, which breaks oil down.

1. There are a series of O-ring oil seals inside the timing compartment as well as elsewhere that ensures there is no oil leakage. A wrong, faulty, improperly assembled or non-existent O-ring between pressurized component mating parts and oil galleys will allow oil pressure to drop because oil can bleed out. This is also a cause of oil blowby out the breather because too much oil slopping around will overwhelm the breather oil separation assembly in each head.
2. Lastly, it may not be an oil pressure problem at all but a faulty or worn out oil pressure sending switch (26561-99, 74438-99) used on all TC88, TC96, TC103, and CVO 110 Twin Cams, which is located at the front of the right engine casing.

Filtering the Oil

There are two biggies here.

1. First, the oil filters before the oil feeds into the engine, not afterwards as in all previous Harley-Davidson models.
2. Secondly, there is a new chrome filter (63798-99, 10-micron; 63798-99A, 5-micron). It still looks like the 30-micron Evolution one. It is still chrome. However, the two successive Twin Cam oil filters cleanse the oil much better because of succeeding lower *micron ratings.*
3. The old camelhair filters from the Shovelhead and Panhead eras only filtered out small rocks; that is if debris-laden oil did not flow around the outside of the oil filter canister. With the Evolution motorcycle, Harley became serious about filtering out impurities as small as 30-microns (30-millionths of a meter).

The 1999-2006 Fathead TC88 filters lower this to 10-microns.

1. In 2006, Harley-Davidson lowers oil filtering (63978-99A) to incredible 5-microns with the 2006 Dyna Glide models and all 2007-to-present TC96, TC103, and CVO 110 models.
2. This and other changes have allowed the Factory to extend service life between oil changes from 500 miles initially, to 1000 miles, and then every 5000 miles.

However, do not take these comments as a license to extend oil and filter changes beyond 5000 mile intervals.

Heat and pursuant oxidation reduce the oil's ability to lubricate after time.

- Also, the additive packages so necessary to maintaining engine health begin to deplete.
- Oil filters begin to clog with the impurities that they so efficiently remove from the detergent oil.

Oil Filter Efficiency

Efficiency is how much particulate is stopped and stored by the filter in any given range such as between 5-microns and 30-microns. Efficiency is expressed as a percentage of how many particles are removed from the oil within a specified range compared with the total amount of particles in the oil.

1. Smaller particulate is also filtered but at a lower percentage rate. A good filter will also remove water that is produced by condensation within the engine.
2. Obviously, larger particles are filtered also and retained at a higher percentage rate than smaller ones.

A quality filter not only extends engine longevity but also removes contaminants that reduce oil life. Therefore, a good filter also extends oil quality but not indefinitely as additives wear out or chemically change with use.

The Oil Filter Bypass Valve

Filtering must be done without sacrificing oil flow, which is where the by-passing relief valve inside the filter body comes in. The relief valve is necessary to keep the filter from collapsing when the flow from the engine into the filter exceeds flow out the filter. It would be nice if this only happened when the filter was not changed often enough, but it appears that it is all too common an occurrence due to finer micron ratings and high viscosity oil. Thus the bypass relief valve is extremely important.

1. Fineness and uniformity of the filtering material determines filtering efficiency of a specified material.
2. If it is superior, the material used will allow more oil flow through it than other substances.
3. Most good oil filters on the market have 90% to 98% efficiency ratings in the 40-80-micron range. For example, Perform filters claim this 90% to 98% rating in the 28-micron to 35-micron range with nominal ratings in the 10-micron to 22-micron range. They also say that their filters have 4-micron efficiencies of up to 20% per pass through the filter. This is for oil that is actually filtered and not by-passed away back into the oil reservoir.

When there is a backup of oil, which causes pressure, the by-pass valve will open allowing unfiltered oil unfettered access back into the oil tank until the pressure subsides allowing more oil to be filtered. This pressure point may be at say twelve pounds per square inch (12psi). Oil backup can compound in cold weather or when first starting your bike because the oil won't flow as well until hot.

For the thinking reader it may now become apparent that a 30-micron Evo filter may filter more oil because its filtering material is not as fine as the Twin Cam one. Theoretically, the 10-micron filter would be more efficient but only if the oil went through the media as opposed to being bypassed back into the engine unfiltered by the by-pass valve. Some Twin Cam owners use a 30-micron Evolution filter for this reason or a 10-micron filter on 2007-to-present Twin Cams that normally fit with a 5-micron filter.

Oil Filter Capacity

Capacity is also extremely important since it defines as how much filtered particulate the oil filter can hold without blocking or impeding oil flow.

1. Impeding oil flow is measured by the difference in oil pressure on the inlet side of the oil filter compared with the oil pressure going out the outlet and into the oil reservoir.
2. Filter capacity is largely dependent on filter surface area.
3. Evolution and Twin Cam filters are pleated back and forth. The size of filter and/or the tightness of the pleating determine filter capacity.

Materials range from paper-like material as in the Evos to cellulose, fibreglass and synthetic media used in the Twin Cam filters. Paper does not remove as small a particulate as say synthetic media, which the 10-micron and 5-micron Twin Cam filters employ.

Changing filters is very important. As capacity to store contaminants is used up so is filtering material. In an extreme case, the filter's capacity might be used up causing oil to back up thereby opening the by-pass valve on a full-time basis with no oil being filtered whatsoever. Pity the engine if the capacity is used up and the by-pass malfunctions in a closed position.

Oil Filter Magnets

Magnets placed on drain plugs etc. help greatly with the ferrous; (steel/iron) materials suspended in the oil but obviously won't catch the aluminum, plastic, brass, or condensation that could be circulating in the system. Non-metallic materials like plastic are not as destructive as metal particulate to the rest of the lubricated parts, but could certainly block small oil passages.

Oil Filter Micron Effectiveness

Filters are only designed to remove by-products of the combustion process plus normal wear particles, which ultimately contaminate the crankcase. They were never designed to catch the overwhelming remains of major component breakdown.

While the 30-micron filter seems less efficient, it will filter more oil through its filtering paper before the bypass valve becomes activated.

By-pass (Relief Valve) Spring Tension

If using an automotive filter on your Harley, it is crucial to ensure the by-pass spring tension. For example if the by-pass pressure is rated at say, 28psi, then oil would back up until it exerted 28psi on the spring. This wouldn't happen in a Harley because the oil pressure rarely exceeds 28psi. Therefore oil would backup and starve the engine for lubrication. However an automotive filter with the correct by-pass tension may have greater efficiency and capacity because of possible increased filter area. Pick a filter with a spring tension in the range of 15psi.

The Twin Cam Oil Pump

Be patient with the next sequence of information, as I will explain it in detail. The oil pump is a:

- Twin-geroter.
- Dual-scavenge.
- Crank-mounted.
- Internally driven.
- Internal dry sump.

You know, the words *dry sump* always used to confuse me and everyone assumed that I knew what it meant. I will not do the same to you.

First, a wet sump stores its oil inside the crankcase.

1. A dry sump stores oil in an external oil tank or reservoir.
2. The wet sump oil pump does not have a return side since there is no external storage reservoir for the oil.
3. Therefore, the wet sump engine bathes in the oil. No modern Big Twin or XL Harley uses a wet sump system.
4. A dry sump must have a return side to the oil pump to deliver the oil back to the external tank.
5. Now, I will explain the old gear-style pump used on all previous modern Big Twins versus the geroter style on the Twin Cam engine from its inception in 1999 to present.
6. The first use on a Harley-Davidson of this geroter, or *Trochoid* pump, was on Sportster models beginning in 1977. I do not have a clue how the name Trochoid came about. However, Nippon of Japan has a patent on it.
7. Sometimes it takes the Big Twin awhile to catch up. The gear pump like that used on the Evolution Big Twin is okay but not the best. It produces *moderate volume and moderate pressure.*

8. The geroter pump produces *high volume and high pressure.* It uses sets of rotors called geroters instead of gears.
9. *Twin geroter* is a little misleading since there are four rotors:

Two for feed; 26464-99 set of 2 for 1999-2006 (inner and outer); 26281-06 set of 2 for 2007-to-present (inner and outer).

1. Two for return also known as scavenge; 26465-99 set of 2 (inner and outer); 26278-06 set of 2 (inner and outer).
2. For clarity there is both a feed set of geroters and a return set of geroters, which is necessary for a dry sump system.
3. The thicker geroters are for the return side while the skinnier ones are for the feed; they fit right over the driving pinion shaft with the oil pump housing over them.

Dual scavenge means that oil is picked up for return to the oil tank from two places in the timing chest, the crankcase oil and the timing chest oil. The dual-scavenge ports or lobes colloquially known as *dual kidney* ports face downwards from the main oil pump body to the bottom of the timing chest in order to suck up oil into the return geroters in order to send the oil back to the external oil reservoir.

The rear slightly longer port scavenges returning oil from the bottom end compartment.

- The front, slightly shorter port scavenges or removes oil from the timing compartment.
- Both ports feed the removed oil into the return side of the oil pump.

Crank mounted indicates that the mounted oil pump is on the pinion shaft although the body bolts to the inboard side of the cam support plate.

Internal is self-explanatory as the pump is inside the engine not outside like every Harley you are used to.

Driven means that the rotors fit over the pinion shaft, and the rotating crankshaft drives them.

One last thing: Evolution oil pump gears mesh with each other side by side, but on the Twin Cam, an inner rotor sits inside an outer rotor, squeezing oil between the two to produce pressure and flow.

There is one less nub on the inner rotor than the outer one.

1. Both rotors have fixed but different centers.
   a) Each inner feed and return geroter is driven and aligns via inside female slots with a corresponding elongated male slot on the rotating pinion shaft.
   b) The outer rotors fit snugly but not tightly and are held in place by the round inner circumference of the inner oil pump body housing that remains fixed and bolted to the inboard side of the cam support plate
2. However, their centers have the effect of being a little offside to each other because the inner rotor has one less outer circumference nub than the outer rotor, which has one more inner circumference nub.
3. This results in a space that opens up creating a vacuum that will draw oil into the gap until the volume of oil fills it, which is equal to the area of the one-less tooth of the inner geroter.
4. The inlets and outlets of the oil pump are timed to seal by the nubs or lobes of the inner and outer rotors as they rotate.
5. As the rotors rotate on their offset fixed centers the space begins to move towards the outlet side of the pump and begins to get smaller. Oil will not compress. Therefore, as the nubs or lobes move, the outlet side will open forcing high-pressure oil out the outlet discharge port.
6. In actual operation, there is a continuous supply or return of oil.

7. Both the oil feed geroters and the oil return geroters operate in the same way to create feed or return oil pressure.

The TC88, TC96, TC103, and CVO 110 oil pump, positions inboard (behind), and bolts to the cam support plate.

The 1999 to 2006 TC88 (excepting the 2006 Dyna TC88), geroter nubs are 12/13; the outer geroter has 13-inward-facing nubs that interact with the 12-outward facing nubs of the inside geroter.

- Oil flows in the feed side between the geroters and becomes trapped. As the pump geroters rotate on the pinion shaft, the oil squeezes into a progressively smaller and tighter space, creating pressure as it forcefully exits the pump.
- The 2006 Dyna and 2007-to-present TC96, TC103 and CVO 110 pump (26037-06) is similar but pumps 10% more feed oil plus the pump scavenges 23% more return oil.
- The new 2007-to-present pump has a 10/11 nub arrangement, which gives it increased capacity.
- Furthermore, there are different length dual-scavenge oil pump ports that face downwards to the bottom of the timing chest in order to suck up oil from the timing chest and from a lower portion, the bottom end and into the return geroters of the return side of the oil pump. The pressure pushes the oil back to the external oil tank.

The Factory-recommended fossil oil is H-D 360, 20W50. Any quality 20W50 API SH or API SJ or API SL rated oil will service the engine well.

Do not use *Energy Conserving I* or *Energy Conserving II* standards, or API SM oil classification, or ILSAC GF-4 classification. These classifications are clearly marked on oil containers.

I prefer the use of synthetic oil once the engine has 1500 miles on it. Fossil oil is not as slippery and lets mating parts wear into each other during the break-in period. My opinion is that further wear is neither required nor desirable once broken in.

Comparison: 1992 to 2000 Evolution Oil Flow

The rest of this chapter sometimes rehashes information already covered in earlier parts of this book. However, the following information on internal oil feed, oil return, breathing, and oil blowby is more comprehensive and is presented in a logical and structured format.

It is worth comparing what went before and probably led up to Twin Cam oiling improvements. This comparison will demonstrate the radical changes that the Twin Cam has employed and improved upon. Historically, one system builds on another, hopefully correcting the shortcomings of the past.

The main differences between the early and late Evolution oiling systems are:

1. The change to an oil pan reservoir underneath the transmission from a gravity fed oil tank on the FLT models that began in 1993 with all models joining in 1994. The Dynas used an oil pan since their inception in 1991.
2. The addition of a top end breather apparatus to separate and vent crankcase air. This began in 1992 and by 1993 all models utilized this crankcase breather located in each head between the rocker arms. Early 1992 models still vented from the crankcase up into the air breather for ingestion into the combustion chamber. Late 1992 models vented directly from each head into the breather.

Some components and functions eliminate because of the new crankcase breathing system.

1. The timing cover nosecone breather tube also known as an air duct tube and drilled air passages are no longer required after1992. This thin metal tube extends a few inches from the inside bottom. It is part of the 1984 to 1991 Evolution breathing system. The new nosecone part numbers are 25254-93A and 25256-93A (chrome).
2. The right pinion crankcase also eliminates its mating breather tube.
3. Thus the external engine breather tube to the air box also discontinues in favor of the new internal breathing system that feeds air via the heads into the air box.
4. The 1970 to 1992 nosecone oil separation baffle plate eliminates, which necessitates a new gasket (25225-93B) from the previous nosecone gasket 25225-70B. The rotary breather valve gear's (25310-82A) breather trap evacuation passage hole is no longer necessary even though H-D does not eliminate the opening. It is no longer serviced by the right engine casing's breather trap evacuation passage so the breather hole becomes non-functional.
5. All of these changes were designed to curtail oil blowby to the outside world. While, the situation improved with the 1992-1993 to 2000 Evolutions, it certainly remained a problem.

All Evolution engines from 1984 to 2000 lubricate by a pressure system that circulates oil from the external oil reservoir, whether a tank or oil pan through the moving parts of the engine; creating molecular films between mating parts and then flowing back to the oil reservoir. There are five oil related functions related to oil flow inside the Evolution engine.

1. High pressure feed.
2. Low pressure feed.
3. Air oiling mist.
4. Crankcase venting air.
5. Oil return.

Internal Feed Oil Routing

1. Either oil gravity (low pressure) feeds on Softail models or is pumped from the transmission oil reservoir on Dyna/FLT models into the feed dual-gear side of the oil pump.
2. The oil pump check valve (H-D 8873), which is a ⅜" ball bearing that sits in a seat blocking oil drain from the oil tank when the engine is not running is held in place by the check valve spring (26262-80).
3. The check valve will rise, allowing high pressure oil feed into the engine beginning at 3psi oil pressure.
4. High pressure oil feeds through an oil passage to the tappet oil screen (24981-70), which locates in the right crankcase behind the rear lifter tappet block. The screen is accessible for cleaning via a plug (26263-80). This screen further filters the oil before it enters the dirt-sensitive hydraulic pushrod tappets (lifters).
5. High pressure oil also feeds to the oil pressure switch behind the lifter/tappet screen. The switch will activate above 5psi turning the oil indicator light off.
6. High pressure oil feeds through a passage past the tappet screen to the base of the front and rear tappet guide blocks where the passage splits into two to enter each tappet block.

7. High pressure oil continues into the hydraulic lifters so they can function. They pump up with the oil pressure, which takes up excess play in the four separate valve trains.
8. The high pressure oil continues up passageways in the center of all four pushrods. This oil flow first lubricates the bottom pushrod sockets where they sit into their mating hydraulic tappet inverted sockets. It then lubricates the:
   a) Top four pushrod (17921-83 rear exhaust; 17924-83 rear intake; 17930-83 front intake and 17927-83 front exhaust) sockets.
   b) Rocker arm (4) sockets (17360-83 rear exhaust, front intake; 17375-83 rear intake, front exhaust).
   c) Eight rocker arm bushings, two per rocker arm (17428-57).
   d) Rocker arm (4) shafts (17611-83).
   e) Oil mist also ensures every component receives a coating.
9. The high pressure oil that caused the relief check valve to open in steps 2 and 3 also causes the oil pressure regulating valve (26400-82) to open. It is located in the tower of the oil pump body in front of the relief check valve. Once open, high pressure oil travels into an engine case passage and into the nosecone gear cover (25269-90, 25254-93A, and 25256-93A etc.) oil passage to feed and lubricate the gear cover pinion bushing (25582-73, 25582-93).
10. The oil continues through an oil passage in the pinion shaft, into the right side flywheel and into the crank pin. High pressure *oil feeds out of one central hole in the crank pin* (23961-80A, 23974-87, 23975-87) to lubricate the 51-bottom end roller bearings, their three cages, the outside of the crank pin and the three connecting rod races. The oil-hole lines up pretty much in the center of the male connecting rod bearing set. Oil must squeeze sideways to lubricate the male bearings and the narrower female bearings and their cages on both sides. Oil then must also make its way between the bearing cages themselves as well as the up the flywheel thrust washers on either end. Oil also drip lubricates these thrust washers via splash lubrication and gravity. Lastly, the oil must lubricate the three connecting rod races that rotate on the 51-roller bearings. Quite a job for one high pressure oil passage. I always use an aftermarket 3-hole crank pin for rebuilds as it distributes oil supply evenly and efficiently. There is an oil supply for each bearing set and connecting rod race.
11. When pressure equalizes throughout the feed system for top end and bottom end, the pressure regulating valve opens further allowing excess low pressure oil to feed back into the feed side of the oil pump cover.

Oil Spray, Misting and Splash Lubrication

Oil spray occurs when oil lying in the bottom of the engine casings is picked up by the rotating flywheels and thrown via centrifugal force about the area below the pistons in the bottom end compartment. Of course, piston location in the cylinders is changing all the time. This oil fling lubricates the cylinder walls and thus the piston skirts. The lower oil scraper piston rings constantly remove this oil above the piston skirts on their downward strokes in order to contain the oil in the bottom end thus preventing it from entering and polluting the combustion chambers. There are either three or four oil holes in the front and back thrust surfaces of each piston underneath and just below but part of the lowest ring groove. This bottom groove houses the oil "scraping" 3-piece ring set that is supposed to prevent oil from passing into the combustion chamber. The upper ring seals compression from escaping the combustion chamber into the bottom end while the center ring supports the work of its mating counterparts.

These small oil holes allow scraped oil to evacuate (drain away) instead of overloading the oil ring set. This action occurs on the intake and power downward strokes of the piston. Scrape is a term that is too harsh for my liking to describe this process since it connotes bad wear in my mind. Wiping might be a better descriptive word.

Wrist Pin Lubrication

Oil fling performs a few other vital functions such as entering a hole on top of the connecting rod, which flows via gravity to lubricate the wrist pin and wrist pin bushing. The wrist pin attaches the piston to the top small-end of the connecting rod. The wrist pin fits through one side of the piston, (boss), then through the wrist pin bushing located in the connecting rod and then into the other side piston boss.

Pinion, Sprocket Shaft and Cam Bearing Lubrication

Oil splash, drip lubrication through an oil-hole passage above the pinion bearings, and oiling mist lubricates the pinion roller bearing that sits in the right engine case. The bearings supports the flywheel or crank pinion shaft and allow it to rotate effortlessly driving the oil pump and valve train. The *single cam journal* end bearing located just above the pinion bearing is lubricated in the same way.

The sprocket shaft bearing set, which supports the flywheel sprocket, (power), shaft through the left side case are fed by splashed oil that runs down the inside left crankcase and into an oiling hole located above the bearings.

Internal Feed Oil Return

1. There is also an oil return passage at the top of the pressure regulating valve to allow oil to bleed off. Without a bleed off mechanism, non-compressible oil could become trapped and prevent the pressure regulating valve from lifting.
2. Top end oil in the rocker area above the combustion chamber returns to the crankcase via a return passage in each cylinder and head. This passage begins at the lowest point inside the rocker chamber thereby evacuating oil and heavier residue oiling mist via gravity.
3. This return oil flows to the lowest point in the *crankcase-flywheel cavity*.
4. The rotary breather valve (25310-82A, 25311-90) is gear driven via its integral gear that times to the cam gear that times to and is powered by the pinion shaft gear (24040-90 to 24046-90 and 24040-93 to 24046-93). The rotary breather valve times to open as the pistons descend in their cylinders. This creates pressure of displacing air that evacuates (scavenging) and carries oil from the crankcase compartment through the open hole in the breather valve and engine case alignment into the nosecone gear compartment. Beginning in 1992, for the rest of the Evolution years, H-D permanently switched back to using the H-D 25310-82A rotary breather valve apparently finding it the most effective at controlling oil carryover (oil blowby).
5. This positive pressure also travels up through tappet guideblock passages into the pushrod covers and into the rocker compartment through the one-way umbrella or flapper valve. The process of oil separation from the air begins to occur. Oil flows back down into the bottom end compartment, while the supposedly cleansed air travels into the air box for re-ingestion and combustion.

6. The oil and air exhausting through the breather valve gear separates in the nosecone via gravity. The oil flows down to the lowest point and into a passage in the right engine case.
7. This passage leads to the oil pump return gears that scavenge the oil for return to the oil reservoir via the oil filter.

1992 to 2000 Evolution Crankcase Breathing System

Crankcase breathing occurs as a result of the pistons pushing up the cylinders creating a vacuum and thus a larger space for air to flow into. The descending pistons push the air out as the crankcase area becomes smaller. The moving air picks up and absorbs an oil mist resulting from evaporates and the churning internal motor parts.

1. The pistons simultaneous downstrokes first force air from the crankcase compartment into the timing (nosecone) compartment and secondly up the pushrod tubes to an umbrella valve (26856-89) in each middle rocker box wafer (17510-92 polished, 17529-92 chrome) that H-D refers to as a spacer.
2. The umbrella valve opens with the force of the entering air. It closes when air pressure decreases preventing the return of any air.
3. The oil in the moving air for the most part separates via gravity and hitting obstructions inside a baffle chamber that forms when the three wafers assemble together. Oil flows to the lowest point in the head where the return drain hole to the crankcase begins.
4. The air travels through a passageway in each head to an outlet where the hollow air cleaner bolts thread into. The air flows through the mounting bolts into the air box for ingestion in the combustion process.

The reader can now compare this to the changes instituted by the introduction of the Twin Cam engine in 1999.

Twin Cam Engine Oil Feed

All Twin Cam engines; TC88, TC96, TC103, and CVO 110 engines from 1999-to-present lubricate by a pressure system that circulates oil from the external oil reservoir, whether a Softail oil tank or rubbermount oil pan underneath the transmission through the moving parts of the engine; creating molecular films between mating parts and then flowing back to the oil reservoir. Oil has four main functions:

1. Cooling by dissipating and carrying away heat caused by friction of parts moving together and from the heat of combustion
2. Cleaning by carrying contaminants produced by friction and combustion to the oil filter for removal from the oil supply.
3. Lubricating by putting a film of oil between moving parts to reduce friction
4. Sealing by preventing leakage past seals and rings. A rubber seal cannot keep oil in or out without having a film of oil to assist it.

There are seven oil related functions related to oil flow inside the engine.

1. High pressure feed.
2. Low pressure feed.
3. Splash/oil-fling lubrication.
4. Air oiling mist.
5. Crankcase venting air.
6. Low pressure oil return.

7. High pressure oil return.

The engine oil feed occurs in the following sequence:

1. Either oil gravity feeds in conjunction with feed geroter pumping on Softail models or is high-pressure pumped from the transmission oil reservoir on rubbermount Dyna/FLT models into the feed dual-geroter side of the oil pump.
2. Rubbermount oil pickup comes from the front compartment of the internal oil baffle into a bottom oil pan passageway that directs the oil upwards to a second galley in the transmission housing, which feeds the oil from the oil pan into the engine oil-feed hose. The oil baffle's function is to re-circulate hot returning engine oil for heat dissipation purposes. The oil pan oil and transmission fluid are separate. There is no connection linking the two even though oil passages do traverse the transmission housing's outer casing.
3. The oil then pressure feeds through the cam support plate and crankcase to the oil filter mounted on the front of the engine's right side for filtering. The clean filtered high pressure oil routes back into the crankcase through the upper hole in the oil filter mount and back into the cam support plate for distribution to various parts of the engine.
4. An offshoot oil passage from this channel connects to a pressure relief valve (26400-82) mounted in the cam support plate near the bottom left side. This is the same relief valve used on Evolution gear drive oil pumps. At 35psi oil pressure, the pressure relief spring compresses' thereby allowing an orifice to open that permits excess oil to bypass back to the feed side of the oil pump for re-pumping.
5. Oil that does not bypass continues by exiting a hole in the inboard side of the support plate that connects to a flange in the crankcase. An oil passage continues through the right crankcase side to its front where the oil pressure sending unit threads into the casing, intersecting with the oil passage. The oil pressure sending unit continuously takes a reading of pressure or lack of pressure and sends an on/off electrical pulse via wiring to the oil light. This oil then exits through the lower hole in the oil filter mount
6. The crankshaft bottom end bearings, crank pin and parent material connecting rod races are fed high pressure oil through a pinion shaft feed bushing in the cam support plate. Oil then feeds into a pinion shaft passageway to the right side pinion flywheel internal passage, and outwards to connect with the oil feed hole in the crankpin.
7. Oil fills the center crank pin reservoir. The oil then squirts out *3-crank pin lubrication holes* to lubricate the aforementioned bottom end components. Oil squeezes sideways between the bearing cages themselves as well as the up the flywheel thrust washers on either end. Oil also drip lubricates these thrust washers via flywheel splash lubrication and gravity.
8. While this is all going on, the high pressure feed oil also fills a main galley in the cam support plate to supply oil to pump up the hydraulic lifters via two crankcase oil passages. One galley goes to the front cylinder and the other to the rear cylinder hydraulic lifter bores. The oil leaves the lifter bore and flows around a slight depression in the middle of the hydraulic lifter body to enter an oil hole in the body on the opposite side. There is close fitment of the lifter body to lifter case bore above and below the depression. The lifter travelling up and down as it follows the dictates of the cam lobe lubricates against the lifter bore via this moving depression.

9. Once the lifters fill with oil, pump up, and create zero lash (spacing) in the valve train, the oil flow then leaves a hole in the center of the hydraulic lifter pushrod socket and enters a hole in the pushrod socket itself to high pressure feed up the center of all four pushrods to the top end. This oil flow first lubricates the bottom pushrod sockets where they sit into their mating hydraulic tappet inverted sockets.
10. Oil feed travels to the top end via passageways inside the pushrods.
    a) Displaced oilified air from descending pistons travels into the top end via the hollow pushrod tunnels surrounding the pushrods to feed through the breather separation assembly in each head's rocker base.
11. Oil feed then exits holes in the top four-pushrod sockets and enters a feed hole in each of the four rocker arm (17360-83 rear exhaust, front intake; 17375-83 rear intake, front exhaust) mating sockets.
12. This oil lubricates the eight rocker arm bushings (17428-57), two in each rocker arm that semi-rotates on its rocker arm support shaft (17611-83).
13. Oil travels down each rocker arm shaft and exits via a pin hole on the outboard side of each rocker arm adjacent to the rocker arm pad that pushes down on the valve stem top to open the valve by compressing the valve springs.
14. This high pressure oil exits as a spray through each rocker arm pin hole to lubricate their respective hard working valve springs as well as the top of each valve stem.
15. The low pressure excess oil flows via gravity to the lowest portion in the head, which is in the exhaust spring(s) pocket to a drain hole, which leads into the drainage return passage in the cylinder head.
16. I now go back to the cam support plate where two small oiler holes each squirt oil onto their respective primary and secondary silent drive chains. This oil squirts because the holes are not large enough to accommodate the oil pressure.
17. High pressure oil then travels to the piston-cooling jets (22307-99); one for each cylinder via the intake lifter bores, which squirts a stream of oil from their two locations at the base of the engine cylinder deck up to their respective piston crown undersides. A check valve in each piston jet opens only when oil pressure reaches 12psi to 15psi. This occurs as soon as the engine operates at an rpm above idle speed. This cooling action relieves about 50^0 F from piston head temperature.
18. This squirted oil also drip lubricates the piston pins through a hole in the bottom of each piston pin support boss.
19. It further splash-drip lubricates the piston pins and piston (wrist pin) pin bushing from the top center area. Some of the splashed oil will drip down on top of each connecting rod small end that has a hole for oil to gravity-flow into. This lubricates the piston wrist pin and mating wrist pin bushing that press fits into each connecting rod small end. The wrist pin attaches the piston to the top small-end of the connecting rod. The wrist pin fits through one side of the piston, (boss), then through the wrist pin bushing located in top small-end of the connecting rod and then into the other side piston boss.
20. Oil Spray, Misting and Splash Lubrication:

Oil spray occurs when oil lying in the bottom of the engine casings is picked up by the rotating flywheels and thrown via centrifugal force about the area below the pistons in the bottom end compartment. Of course, piston location in the cylinders is changing all the time. This oil fling lubricates the cylinder walls and thus the piston skirts.

The lower oil scraper piston rings constantly remove this oil above the piston skirts on their downward strokes in order to contain the oil in the bottom end and timing compartments thus preventing it from entering and polluting the combustion chambers. There are 3-oil holes in the front and back thrust surfaces of each piston underneath and just below but part of the lowest ring groove. These small oil holes allow scraped oil to evacuate instead of overloading the oil ring set. This action occurs on the intake and power downward strokes of the piston. I prefer the term *wiping* to scraping. This bottom groove houses the oil *scraping* 3-piece ring set that is supposed to prevent oil from passing into the combustion chamber.

21. The single upper ring seals compression from escaping the combustion chamber into the bottom end while the center ring supports the work of its mating counterparts above and below.
22. Oil splash runs down the inside of the left engine casing. Some enters an oil hole above the bottom end 1999 to 2002 Timken sprocket shaft bearings (H-D 9028) or the 2003-present roller bearing (24004-03, 24004-03A, 24605-07) to lubricate the power-side bearing(s). Oil mist and splash lubricates the inboard side of the right case pinion bearing (24623-99, 24604-00D, 24605-07), and the *2-inboard cam bearings* (1999 to 2006 H-D 9198, 2007-to-present H-D 9215).
23. Engine oil pressure is 35 psi at 230^0 F at 2000 rpm.

Twin Cam Engine Oil Return

1. Gravity drain oil from each cylinder head flows to the lowest point to an internal head oil passage locating at the bottom of the exhaust valve spring pocket.
2. Oil flows straight downwards through the head and cylinder oil passage. Both the head-to-cylinder and cylinder-to-engine case deck have an in-channel intersecting hollow-dowel pin (16595-99, 16595-99A) sealed by an O-ring (H-D 11273) to ensure no oil leaks at these two junctures for each head's drainage.
3. Unlike the Evolution, whereby oil drains into the bottom end compartment, Twin Cam *oil drains into the timing compartment*. The front head-cylinder drain oil is serviced by a passage at the front of the left engine case while the rear head-cylinder passage is at the rear of the left engine casing. The oil travels vertically or sideways through another hollow dowel (16574-99, 16574-99A) that connects and seals the juncture between left and right side engine cases. The draining oil continues through the right engine case, front and back, and empties into the cam (timing chest) compartment. The intersecting juncture dowel pins are just another example of how hard H-D engineers worked to make this engine oil tight.
4. This oil now drains again to the bottom of the timing compartment via gravity where it is picked up (scavenged) by the front, slightly shorter-oil pump scavenge lobe for removal to the oil return geroters. There are two oil pump scavenge lobes, simultaneously removing oil; one for the bottom end compartment oil return and the other for the timing compartment oil return.
5. Surplus oil from gravity-draining splash lubrication of the bottom end sprocket shaft bearing(s), the pinion bearing, and the two inboard cam bearings flows down to the bottom of the crankcase compartment. It collects in the sump area at the lowest point and then flows into the cam compartment via an internal channel where the second, slightly longer rear-oil pump scavenge lobe feeds this removed oil into the return geroter side of the oil pump.
6. The removed oil via the scavenge ports is pressure fed by the return geroters into an oil passage in the cam support plate.
7. The returning oil then enters a junction passageway on the inboard side of the cam support plate and enters a crankcase oil galley. The oil then exits the engine from the upper fitting at the rear side of the right engine case to return to the Softail oil tank or the rubbermount oil pan underneath the transmission housing.

8. Softail return oil is not re-circulated but simply enters a fitting at the top of the Twin Cam oil tank. Evolution and Twin Cam FXCW and FXCWC Softail oil tanks have a fitting at the bottom and return oil flows up a fixed internal standpipe to near the top of the tank.
9. Rubbermount return oil flows via an oil line to the front of the transmission housing and into a passageway that drains into the oil pan (FLT 62489-99 black, 62490-99 silver) at the front of the oil pan baffle (62830-99). However, the Twin Cam oil reservoir recirculation is different from the Evolution. The engine oil in the Evo reservoir under the transmission has a feed and return at the front. This results in using the same oil constantly while fresh oil hangs around at the back. This inefficient situation allows for higher temperatures that are not necessary, promoting oil breakdown because of oxidation. Heat causes oxidation, which is always the main enemy of oil. Furthermore, pollutants do not disperse evenly throughout, allowing the benefit of dilution. Beginning in 1999, the Fathead TC88 eliminates this inefficiency by using a baffle plate in the oil pan that ensures the returning oil follows a tortuous path throughout, ensuring that it fully circulates. H-D further upgrades the oil reservoir baffling and oil recirculation in 2009. This ensures more efficient cooling and the use of all the oil all the time.
    a) The 1999 rubbermount Twin Cam return oil now directs to the rear of the oil pan along either side of the baffle.
    b) The baffle is spring-tensioned (62828-99) to prevent the oil from taking any shortcuts.
    c) At the oil pan rear, the baffle opens up to allow the return oil to flow through the center back to the front of the pan.
    d) The slow oil re-circulation through the oil dissipates oil heat. This feature improves through the Twin Cam years.
10. Pressure equalization between the engine and the oil pan achieves by a hose running from a fitting behind the rear tappet cover (17966-99 chrome), which connects the timing compartment with the oil pan through an independent passage in the transmission housing connecting into the oil pan. Without this breather connection, continuous oil circulation would impede.
11. Pressure equalization with the Softail oil tank also achieves with the traditional engine-to-tank vent line. The Softail vent line simply enters a fitting at the top of the Twin Cam oil tank. Evolution and Twin Cam FXCW and FXCWC Softail oil tanks have a fitting at the bottom and venting air flows up a fixed internal standpipe to near the top of the tank above the oil's level. This is the reason not to overfill an oil tank as it may hamper venting.

The Twin Cam Breather System

The new Twin Cam three-stage breather separation system while having similarities to the late-Evolution system is much further refined.

1. The oil separator utilizes physical principles and removes most of the oil out of the air, and lets it flow via gravity back into the timing chest. The separator does this by forcing the oil to follow a tortuous path that allows the gases to separate from heavier oil molecules and escape.

This is a new process for H-D engines. The gaseous mixture must interact with the walls and turns of the separator pathway. The mixture is unable to deal with this interference and heavier molecules of oil liquefy. Wall temperatures are cooler, also further causing vapor to liquefy and drain away.

1. The oilified air now travels through the flapper valve (26858-99), which is a rubber, umbrella-shaped, one-way valve that lets air out of the lower engine but will not allow it back in.
2. This part also exists in the 1992 to 1999 Evolution engine. If overwhelmed, the flapper valve will let the errant oil out along with the air.
3. A new open cell-foam part (63815-99) shaped like a one-inch-long barrel, then scrubs oil from the air rushing through. The foam barrel is very porous and air can easily traverse through the foam. Again, heavier oil molecules will liquefy when presented with challenges like the foam's complex pathways.

Factors Aggravating Oil Blowby

Assuming that there are no mechanical causes like a missing or crimped seal, the two most aggravating factors that will cause or exacerbate existing blowby are:

1. High rpm riding.
2. Sustained highway riding.
3. Increasing the *swept volume* or cubic inch (cubic centimeter) displacement of an engine via big bore and/or increasing engine stroke.

The reason for increased blowby potential is that with high rpm riding, sustained highway riding and/or an increase in engine size, the amount of air transferring out of the crankcase into the air box increases. The increase of air brings with it an increase in the amount of oil evaporates or small droplets carried by the boosted air-movement. Droplets especially are vulnerable to separation from the air by gravity, changes in direction, or slowing air.

My experience is that bikes that are ridden conservatively for short trips rarely suffer any blowby of consequence unless there is a mechanical cause. The third aggravating factor that will begin and/or increase blowby is to increase engine displacement. This is a favorite of Twin Cam riders. Even the Twin Cam can suffer from blowby in spite of the most effective breather oil-mist separation system thus far. However, I also believe conservative riding habits will also tame blowby with this scenario. This begs the rhetorical question of why such a rider would increase engine displacement in the first place. Briefly the process of transferring air inside the Twin Cam occurs as follows:

1. Both pistons move downwards and upwards in their respective bores in tandem.
2. However, the pistons will be on opposite strokes of the engine cycle.
3. Therefore, on the downward piston travel, one piston will be on its intake stroke while the other is on its power stroke.
4. Furthermore, on the upward piston travel, one piston will be on its compression stroke while the other will be on its exhaust stroke.
5. The space below the sealing piston rings shrinks in area as the pistons descend together.
6. The air that fills this shrinking space forces through the rollers of the pinion shaft bearing separating the crankcase compartment and the cam/timing compartment.
7. Oil vapor and small molecules of oil suspend in the rushing tumultuous air.
8. The air continues to force through the timing compartment and up the hollow pushrod tube covers into the rocker box area above the heads.
9. The air, which is really an air-oilified mist, travels through the breather apparatus that locates in each rocker box between the valve train's intake and exhaust rocker arms.
10. The breather apparatus separates the majority of the oil from the air.

11. The oil drains away via gravity for return to the timing compartment.
12. The air follows a convoluted pathway, which further separates any remaining oil before it exits each head into the carburetor/EFI breather box.
13. The air is re-ingested into the engine's combustion chamber via a vacuum created on the intake stroke.
14. Thus the re-circulation of crankcase vapors feeding into the combustion chamber effectively burns any remaining pollutants.

Twin Cam Oil Blowby Control

The Twin Cam system very much improves the 1992 to 2000 Evolution breather oil separation control. The Twin Cam retains the flapper valve in its specialized breather apparatus that locates between each set of rocker arms. Air flows upward through the pushrod tubes exactly the same as in the Evolution system. It enters the breather apparatus into the baffle compartment through oil filter gauze, which scrubs oil from the air. There are pin holes in the bottom of the rocker plate for this scrubbed oil to drain out.

Then the cleansed air passes through the umbrella (flapper), valve. The air pushes it open to allow passage but when the air pressure stops the flapper seals the passage not allowing the air to flow backwards. If there were still oil in the air as would be the case with an engine suffering blowby, the oil would not be able to reverse direction either. Oil getting by the flapper valve is destined for the outside world albeit still trapped within the system in the air box. Some oily vapor could be sucked in through the carburetor or EFI induction body and burned in the combustion chamber.

Once past the flapper valve, air is directed down through the breather apparatus, through holes in the bottom that are aligned with corresponding holes in the rocker arm supports and into a passageway cast into the head itself. The air exits through this passageway, through a hollow breather bolt and then into a breather tube that directs the air into the inner confines of the air filter element. The induction air intake will ingest the majority of this for recycling back into the combustion chamber for burning.

This improved breather air-oil separator arrangement is all about extricating gaseous oily substances from the air to allow the engine to breathe cleanly. The breather is supposed to prevent oil from puking all over its exterior.

The Twin Cam Changes Engine Breathing and Oil Scavenging

- The 1999-2006 dual scavenging pump action in the Twin Cam supposedly results in less oil mist going to the top end for separation. I must say I agree with this but sometimes it too is overwhelmed.

- In 2007 to present, oil pump scavenging increases substantially to once again further attempt to combat blowby.

Furthermore,with previous model Harley-Davidson's, a rotating breather gear with an opening timed to the descending pistons locates in the timing chest. It brings oil from the crank compartment into the timing area. The gear drive oil pump return picks (scavenges) this oil up.

However, Twin Cam oil pump dual-port scavenging does away with further need for a breather gear. Thus, the Twin Cam design eliminates the breather gear that served well in modern H-D use from 1936 to 2000. The advent of the overhead valve Knucklehead in 1936 heralds the beginning of the modern Harley-Davidson engine. Dual port scavenging replaces the need for a breather gear system in the Twin Cam.

Oil return now flows from the top end into the timing chest rather than into the crank like on the 1984 to 2000 Evolution, 1966 to circa-1985 Shovelhead, 1948 to 1965 Panhead, and the 1936 to 1947 Knucklehead.

Evolution and Twin Cam Oil Return from the Engine

There is less oil to scavenge in the Twin Cam crank and more in the timing area because oil returning from the top end flows right into the timing chest. In predecessor engines, this returning oil drains into the crank compartment to slosh around on the flywheel bottoms, causing inertial drag. Thus, a minor speed advantage occurs because of less internal frictional loss-of-horsepower with the new system also.

Conclusion

Blowby has always been a worry as government concern with the quality of the environment began to manifest itself in the years preceding the Evolution motorcycle. Previously, crankcase oil venting was used for exposed rear chain oiling.

The Evolution oiling system divides into two generations that base around the containment of crankcase oil venting. The 1984 to 1991 Evolutions simply directed the crankcase vent line up into the air box. Gravity separated some of the oil while the rest of the oily mist was re-ingested into the combustion chamber for burning. The second generation 1992 to 2000 Evolution oiling system made a double attempt at separating oil inside the engine with an umbrella valve and a baffle chamber before transporting the air into the air box for re-burning.

However, at the end of the day, the Evolution developed the most advanced lubrication system to date. The improved Twin Cam breather venting separation that is a further refinement locates in each rocker box between the exhaust and intake rocker arms.

[1] Report of the House of Representatives. United States of America. *House Report No. 93-1197, 93rd Congress 2nd Session.*

CHAPTER VI

Twin Cam Heads: Deficient Air Flow

Who was to know without testing that the 1450cc Twin Cam heads would flow less air than the 1340cc Evolution?

Engine efficiency and resultant power is all about air. Gasoline cannot burn unless mixed in correct proportion with the oxygen found in air. If there is a limited amount of air in the combustion chamber, only a proportional quantity of gas is able to ignite and burn. Ignition creates heat, which expands generating pressure. The expanding heat/pressure pushes the piston forcefully down on the power stroke.

Why would the Factory not install more air-capable delivery heads on the Twin Cam? Two reasons I think;

The first, as usual, has to do with controlling emissions. The Twin Cam is the most efficient traditional Harley engine ever produced in reducing harmful emissions.

1. The Factory must think of two things in engine head and combustion chamber design; one is to produce power and the other, of course, is complete combustion to limit emissions. I feel that the TC88 head and its TC96, TC103, and CVO 110 counterparts produce acceptable power relative to what has gone before. However, if comparing power and torque output to other brand of bikes of the same size, a deficiency is readily seen.

This acceptable power output for a Harley-Davidson is then married to a head that will meet current emission dictates.

2. In my opinion, the second reason for a 1450cc head that flows less than the Evo 1340cc predecessor is for up-selling Screamin' Eagle performance upgrades.

Harley-Davidson viewed the huge aftermarket industry that enjoys a symbiotic relationship with the manufacturer as a target. I think that Harley is in denial over the mutually beneficial nature of the relationship. It could certainly see that the aftermarket benefited from its motorcycle production and distribution. It had difficulty acknowledging that the aftermarket offered improvements that the Factory could adapt to make its product better.

Harley-Davidson believes that this is a market-share rightfully theirs. The Factory wanted that market to complement its own. More importantly, I think they coveted the attainable profits.

The two main divisions of this potential up selling aftermarket were performance and adding aesthetically pleasing personalizing components (called add-ons). For our purposes here, we will concentrate on the performance end.

- In the Shovel era 1966 to 1985, no one considered co-designing performance upgrades or add-on parts in tandem with the stock engine development.

- In the Evolution years (1984 to 2000), H-D aftermarket performance parts played catch-up with stock engine development in the early years. By the time of the Evo's mature years, the Factory had caught up and Screamin' Eagle (www.harley-davidson.com) offered a full complement of upgrades.
- The Twin Cam designed in tandem with Screamin' Eagle in a well-thought-out program that offered quality; a comprehensive selection, and the ability to up sell parts in addition to the vehicle sale.

The intent was to introduce the full complement of S.E. upgrade parts and components with the unveiling of the new engine in late 1998. Harley was 90% there. The other 10% came soon after. All of this occurred before the aftermarket developed its first part for the new Twin Cam!

The H-D program is so successful that only the finest aftermarket components are able to survive. Darwinian Theory eliminated substandard components and ensured that quality would get even better. The aftermarket reacted the only way it could…by further improving quality and choice for the eager riding consumer.

This game of catch-up required a shortcut. The aftermarket began the process of adapting to and transferring increasing amounts of a mature and superior automotive technology over to the V-twin. This had already started to happen and would have continued at a slower pace. However, the Factory was far ahead of the aftermarket and a frenetic pace of adaptation began. The rider benefits immensely.

The Information Gap

No one knew anything about the Twin Cam except for some Factory people involved in its development and production plus the lucky few like myself. Many of the new business-type dealers do not always have a full mechanical knowledge. Dealers were scrambling to answer all the questions put to them by an enthusiastic customer base. However, they did know how to up sell and sell they did. H-D dealers had never been so successful.

A strange thing began to occur soon after the introduction of the Twin Cam in 1999. Without regard for the limited flow capabilities of the heads, most dealers began pushing the 1550cc (95c.i) upgrade kit for the new engine. Who would have suspected that the venerable Harley-Davidson would begin to evolve this type of engine design with a view to marketing upgraded performance parts?

I feel it is not fair to the consumer if some parts are under-engineered for a purpose of creating an aftermarket, instead of designing and incorporating these improvements into the finished product. Realistically, this is capitalism at its finest.

I can unashamedly say that I was taken in when first observing the Twin Cam head design in Milwaukee in early 1998 because it was obviously superior at first glance. The heads seem superior within limits, and they are in design, but not in the flow of air. The TC88 bathtubbed combustion chamber shape we were familiar with on high-performance aftermarket Evolution heads leads the observer to draw wrong conclusions as to head flow.

The round flattop piston rises in its cylinder on the compression stroke and squishes up against the bathtub design. This forces the air/gas mixture turbulently into the chamber, inducing superior flame travel and a much higher percentage of burn.

Then I learned that the compression ratio is higher, 8.8:1, compared with the Evolution's 8.5:1. Everyone knows that increased compression leads to more torque and thus horsepower.

Visually, the TC88, TC96, TC103, and CVO 110 heads look great. A performance mechanic such as me can readily see the need for porting and perhaps some polishing but I see that in any stock head.

The Twin Cam Lung

The Twin Cam does not have the lung capacity for the engine to achieve the results of coordinated efficiency.

Before I go any further, I would like to state that there are many fine and knowledgeable Harley dealers and aftermarket shops. Furthermore, they have the customer's best interests at heart.

So why do other dealers keep selling 95" big-bore kits with no headwork to accommodate the increased cubic inches?

- Why do they not educate the consumer that sufficient air delivery is essential to the bigger cubic-inch displacement in order for the increased displacement to work to its true potential?
- Ignorance of the product is the only thing that I can think of. In some cases, there was an information gap that still has not been fully addressed. Everyone was on a very steep learning curve with the advent of the Twin Cam. The introduction was such a well-kept secret. The reason is partially due to H-D creating its own aftermarket for the first time in necessary secrecy, well in advance of everyone else in the market place. I believe one major reason the Factory wanted to keep the Twin Cam design a secret to foil an aftermarket response.

Mom-and-Pop Dealerships

In 1999, many dealers knew nothing but the mantra of what to sell and how it affects their bottom line. Some had a credibility they did not deserve. The credibility is born from the fact that they are the official representatives of Harley-Davidson and/or that they have impressive mega-million-dollar operations. These are what I call the capitalistic businesspersons cashing in on the then Harley boom.

In fairness, I enjoyed advance knowledge; had the advantage of having the designing engineers teach me repeatedly; I had time to think about what I learned and to digest this encyclopedia of information, and above all I benefited from being a Harley mechanic for twenty-two years with a physics background.

Do not get me wrong. These new-type business people were and are part of the formula for Harley-Davidson to survive and to prosper almost beyond imagination. Harley needed to get away from the pure enthusiasts with little or no business acumen in order to survive.

In the old days, the Harley Dawgs ran the dealerships. A lot of them were mom-and-pop operations. They were dedicated to the sport and the lifestyle. If they made a little money then that was okay, too. However, I will tell you one thing, not only could "pop" fix anything that ailed your motorcycle but "mom" could also rhyme out the part numbers by memory and diagnose a mechanical problem without batting an eyelash. They would both be riding on their day off, if they ever got one, or would be at some motorcycle event having a great old time beside you and me, their customer/friends.

Donny's Blasts from the Past: **Mouldy**

When I first started riding Harley's in 1969, my local dealer was a crusty old bugger we named Mouldy. His wife was nicer. She would bring down his homemade hot lunch from upstairs where they lived; serve customers and give mechanical advice while Mouldy ate behind the worn, unpainted wood parts counter. The wooden plank floors had forty years of oil and soil worked into them, emanating a nostalgic smell I miss greatly.

On the weekend, which consisted of Saturday night to Sunday night, Mouldy and his four employees would jump on their rigid Knucks, Pans, and the odd swingarm Shovel and ride 500 miles to 1,000 miles, never mind the weather.

They knew what was going on with the product line inside and out. If a new engine came out, an evening or three spent with friends taking her apart and hashing out the new product ad infinitum was the norm. This was part of the trip, and it was fun.

Say what you want; but these old-time dealers were very knowledgeable. For the current good dealers out there, you know whom I am talking about, and it is not you. The businesspersons will not get any dirt under their fingernails. There is a local dealership in my hometown that fires mechanics if they leave oil spots on the floor under their bike lifts. Some of these new people do not want to learn about mechanics nor do some have the aptitude. However, they can go to seminars and read sales literature…sell, sell, sell…and they can read their financial reports over cocktails in places mom and pop never knew about nor wanted to.

However, the pendulum necessarily had to swing from mom and pop, to those who were capable of running bigger operations for the increased demand that was essential for Harley-Davidson to survive. There would be no Harley-Davidson today if the Factory hadn't the foresight to do this, yet I miss the old dealerships so much.

The Big-Bore Kit

The two top H-D aftermarket up-sellers in 1999 and may still be today are the Screamin' Eagle breather kit that improves inhalation of air and some off-road exhausts to increase exhalation of spent exhaust gases. So far, this is good! Improved air flow has the benefit of also adding anywhere from three to six horsepower with these two simple and relatively inexpensive modifications.

The third big up-sell was 95-inch big-bore kits for 1999 to 2006 TC88's or a 103-inch big bore kit for the TC96. Both produced a higher capacity lung with a too-small breathing apparatus. This upgrade requires disassembling the top end and installing the 95c.i or the 103c.i big- bore kit. This is accomplished by increasing cylinder bore diameter from the stock TC88 and TC96, 3 ¾" to 3 ⅞". Different pistons are required for each kit because the TC96 receives its extra cubic inch displacement from an increase in engine stroke. Both the TC88 and the TC96 share the same bore size.

From a performance point of view, this increase in engine displacement or *swept volume* is perfectly safe and does not reduce engine reliability or longevity one little bit.

The head ports that comprise the inhale/exhale tracts cannot handle the volume at 100% capacity. So what are we left with? More power, surely, but not maximum power. The chambers require more air to service this size engine, by any stretch of the imagination.

Twin Cam Heads Flow Great for a 1200 XL

Let's examine the stock Twin Cam heads. They are mediocre from a performance point of view. The design is superb when compared with technology that Harley has used in the past. Bathtub-combustion chambers are the first things you notice when the TC88 engine is apart. The bathtubbing is more of a rounded rectangular shape much like on some early Evo Sportster heads, rather than the bathtub kidney-shaped configuration that used to be on high-performance Evolution heads.

The Evolution Big Twins have a combustion chamber shaped like the letter *D*. Inside the D is a suddenly cut-off rounded chamber. The rest of the circle, a reversed and thinner D is flat and even with the surrounding gasket surface. This is a squish band. A flattop piston squeezes up against this flat squish band, squishing the air/gas mixture turbulently into the D chamber, promoting better flame travel and a much higher percentage of burn. This is the main reason that the Evolution is faster than previous engines, such as the Shovelhead.

The TC88 bathtub chamber is small; having only 85cc volume, which is why the compression ratio is higher at 8.8:1 compared with the Evolution's 8.5:1. The Evolution chamber measured in at around 82cc in later years. The TC88 cylinder bore is larger than the Evolution. It is a principle of physics and mechanics that the larger the bore the larger the combustion chamber must be to maintain the same compression ratio.

With bathtubbing, there is a flat squish band all around the chamber so that the big 3 ¾" bore flattop piston squishes the air/gas even more turbulently into the chamber, promoting the better flame travel and highest percentage of burn of the two different head configurations. In comparison, Shovelhead and Panhead hemi-shaped chambers are not even in the ball game. Their percentage of burn stats is minor league.

The permanent mold TC88 Twin Cam head has the same size intake valve as the Evolution, but the exhaust is about .030" smaller in diameter. However, TC88 heads flow less air than Evo heads because of the smaller intake and exhaust tracts. Therefore, they have insufficient air flow for the smaller 1340cc Evolution also. The design would aid combustion better than the stock Evolution combustion chamber but cannot service enough air.

We are getting close, though. If TC88 stock heads would fit on a hopped-up 1200 XL, I bet they would come into their own as a superlative head. It has a superior design flowing more than enough for this smaller displacement. Of course, the heads are not interchangeable, and I use the above comparisons to demonstrate that both design and flow rate are necessary for near-100% combustion, which promotes engine-breathing efficiency with speed as a by-product.

Aftermarket Heads

The Screamin' Eagle Twin Cam heads work well as they increase the flow to the combustion chamber. The question is why they are not on stock TC88's right from the Factory. Harley has created an aftermarket for it to increase sales. Would sales increase by installing better or maximum flowing heads on the stock machine? Probably not, since it would become the norm.

For me, Screamin' Eagle performance catalogs can be difficult to understand; they must be read carefully and patiently. Nuances concerning specific parts and fitment may be subtle and easily missed. They change yearly with additions and deletions.

In general, at the time of writing, there are four different-style upgraded heads sold by Screamin' Eagle for the Twin Cam. I have compiled a much larger list of Screamin' Eagle heads, in use between 1999 and 2010 with a description of each along with the various other aftermarket performance heads, such as Edelbrock (www.edelbrock.com) and S&S (www.sscycle.com) in Volume II: *Performancing the Twin Cam.*

I constantly see engines with a set of Screamin' Eagle (S.E.) heads that would achieve more performance with a different set of S.E. heads. A good understanding of performance physics will lead the consumer in the right direction. A knowledgeable person is required for advice on a head kit purchase. Suffice to say; which is the best are another story and a complicated one because for different applications with varying support parts, I am sure each comes into its own.

The Best Parts

Sometimes I receive e-mails or comments that infer a particular manufacturer's part is my favorite. The connotation that I perceive from these comments is that I am promoting preferred manufacturers' parts or kits. After decades of working on and performancing Harley-Davidson's, I do know what works best where and what does not.

Confusion may arise because a particular part may work well in combination with certain other upgraded parts but not as well in other combinations. If I do refer to particular parts, it is because they have worked well for me in the past.

I recommend the best part for the job at hand. Many times, it may be a stock Harley-Davidson part, such as the late-style Nippodenso starter motors over the previously used Prestolite or Hitachi ones. It may also be a superb aftermarket part, such as a higher cranking starter motor based on the Nippodenso design. Some aftermarket producers like S&S, JIMS (www.jimsusa.com), Wood (www.woodcarbs.com), Andrews (www.andrewsproducts.com), or a host of others are superlative. Their quality control has become legendary in the industry and the marketplace.

Massaging Stock Twin Cam Heads

The Twin Cam lungs cannot operate at peak efficiency without increased breathing capabilities. Porting and polishing stock heads with a little valve work, such as installing Evolution exhaust valves in TC88 heads will work wonders for engine efficiency and releasing horsepower that is already there but previously suppressed.

The Evolution valve head is .030" larger than their Twin Cam counterparts and allow more exhaust gases to purge from the combustion chamber. The valves fit easily and only require re-cutting the valve seats.

Cutting valves seats where they interface with the valves is extremely important, both for sealing the combustion chamber but also for air flow capability. Increases in air flow dramatically improve with quality work within one-half inch of the valve seat. This is where the majority of flow improvement will come from.

Compare this with only about a potential 1% improvement by polishing the inside of the intake manifold to a lustrous shine.

Performance and Efficiency 101: Cutting the Valve Seat

Valve seats if cut at one angle only give demonstrably poor air flow results compared with a standard three-angle valve cut that produces a satisfactory production outcome. Five-angle seat cuts produce far better air flow increases. If a seven-angle cut is attainable, this will give the best results.

1. Normally the base seat cut in the head where the valve head actually touches and seals the combustion chamber is at 46^0 while the valve face cut is at an interference fit of about 45^0.
2. The adjacent cuts to the heads valve seat will be at 30^0 and 60^0. This produces the three-angle cut.

3. With these two adjacent cuts, I can determine the width of the valve-to-seat center contact area.
    a) This is very important as a wide center contact area may have more longevity before re-cutting is again required but will not flow as much air as a narrower cut.
    b) A very thin center contact area will produce the most flow but may not have satisfactory longevity before a rebuild is necessary. I use this thin-cut on a race bike.
4. Therefore, on a street bike, I need a compromise valve-to-valve seat center contact area, both to ensure good air flow and engine longevity.
5. I can also move the center seat contact area out or in to place it where I want on the valve face. I do this by cutting one adjacent cut deeper and the opposing adjacent cut lighter.
6. For best flow, I will generally place the seating area close to the rim of the valve.
7. However, I will not generally put the seat right at the rim except on a performance bike, as this will lead to a premature compromise of the contact area from the searing combustion heat.
8. A five-angle valve seat cut adds additional 15° and 75° cuts.
9. If looking at the seat from one side to the other, the cuts will be in the following sequence: 15°, 30°, 45°, 60°, and 75°. If looking at it from the opposite side, the figures reverse.
10. The seven-angle cut will add two cuts, one at either end, say 7° and 82° further rounding the seat.
11. The thinking mechanic will decide on the angles for these two cuts depending on the contour of the head port approaching the seat and the contour of the combustion chamber moving away from the other side of the valve seat.
12. The key word is *rounding.* I want and need a rounded valve seat to promote the easy flow of air by removing or modifying impediments to the volume of flow.

Performance and Efficiency 102: Valve Seat Fitment

The valve seat is a separate part pressed into a cutaway in the head. This is necessary because the seat is made from a very hard steel alloy in order to withstand the pounding of the valve returning to the seat thousands of times per minute. It must also withstand the extreme heat that seeks to burn away the thin and thus vulnerable seating area.

The head composition is from a much softer aluminum alloy. The alloy could not withstand the pounding or the concentrated heat.

1. The seat abutment where it contacts the head in the port, whether it is the intake or the exhaust port, is also crucial to uninterrupted air flow.
2. If there is an overhang, it must be radiused.
3. If an under-hang, the seat abutment requires contouring.
4. Addressing valve guides that stick down into the port is a must. I do this in a variety of ways, such as beveling the guide itself so that a pointed as opposed to a rounded edge meets the flowing air. In some situations, a rounded guide works well also.
5. The aluminum port material as it approaches the guide must shape similarly.

The reader can see that this is all about easing impediments to the flow of air. This is not work for amateurs. It is also not work for many mechanics, either since skills in wind-tunnel theory; physics and mathematics are also necessary.

The Flow Bench

Hundreds, if not thousands, of hours of work on a tool called a *flow bench* will teach the prospective porter what works and what does not. The flow bench will also teach the student the physics of air flow as the valve opens and closes.

Measurement of air flow is in cubic feet per minute (cfm).

- The volume of air passing through the port changes as valve lift or valve opening increases or decreases.
- This gets complicated very fast as the reader can now discern a relationship between cam lift and air flow. We need to think about the goals we are after.
- Where do we want maximum air flow that leads to maximum power?
- I now begin to design the power curve, where power comes on and at what rpm it will begin to taper off. This involves other factors like cam lobe design and compression ratios.

I examine these subjects extensively in Volume II: *Performancing the Twin Cam.*

Merrily cutting and grinding away just does not make it! I cannot tell you the number of reworked heads that I have seen by those that think they know what they are doing that actually reduced air flow rather than improving it.

Visualizing Air Flow Characteristics for Cylinder Head porting

It is easier to understand air flow if the reader visualizes a river and how water acts as it makes its way downstream. A narrowing may increase flow, as the same volume of water must pass in the same amount of time. The weight or pressure of the water behind will increase the speed of the water to accomplish this. Similarly, a widening will cause the water to slow down as the pressure from behind eases. These examples are simplistic but demonstrative. I have just described a law of physics called Bernoulli's Principle, which has to do with the movement of gases or liquids.

Many years ago, one of my mentors named Red, who designed the Qwiksilver carburetor now produced by Edelbrock, explained the principles of his work to me by using the river analogy. Red told me he spent hundreds of hours studying the flow of water whether at a beach or in a river in order to design high-flow performance and efficient carburetors. He told me to go to a stream and look for a rock in the middle of the water. I did so and studied how the water moved around different impedimentsI looked for shapes that allowed the water to flow easily over and around it. Then I studied shapes that impeded flow. It does not take long before learning how to shape the rock to improve flow.

This was wisdom born out of simplicity from a man of little formal education. I followed Red's advice. I cannot look at flowing or moving water now without viewing its characteristics and analyzing why it is moving the way it is. It is very interesting and predictable, *as is head air flow.*

Polishing Head Ports

Many misunderstand the polishing of ports.

Exhaust Port Polishing

I polish exhaust ports because I do not care about the exhaust gas-mixture composition flowing out. It is waste, and I want to get rid of it as soon as possible. Therefore, I polish the exhaust port tract to speed up the exit of bastardized gases. A mirror shine is not necessary for expedient elimination of purged of exhaust gases. This is for marketing purposes to make you the consumer feel better.

If purchasing some ported and polished heads some shops will polish the exhaust tract a mirror shine. It is beautiful. Seeing your face mirrored as you look at the lustrous port will make you feel all warm and oozy inside. However, it is not necessary. You will not be able to see it when assembled and the bike is running. Even if you could, the exhaust gases will blacken it in short order.

Do Not Polish Intake Ports

The intake tract is a different story. I do not polish this port, as all my attention must direct at the porting. Porting is reshaping the intake and exhaust tracts to encourage more flow. I leave the intake tract unpolished especially in the inefficient hemi-heads like the Shovel or the Ironhead XL to encourage the entering air/gas mixture to mix. Theoretically, the rough texture of the port walls will cause some turbulence to assist in the mixing of the fuel with air so that it is better able to burn. I will take turbulence *in an inefficient head design* where I can get it, even if not a lot, as it will assist in the fuel burning. There has always been controversy over how true this is. There are even misguided porters who believe in polishing the hemi-head intake, but they are a minority.

I think where the confusion may lie is in the type of head design and fuel delivery.

Hemi-heads do not mix the air and fuel mixture efficiently so they need all the help they can get in the intake tract. Therefore, turbulence in the intake tract assists in mixing the air and gas. However, turbulent air is a slower moving air.

1. Evolution and certainly Twin Cam heads with squish bands mix the air/gas efficiently so we want to get as much into the combustion chambers as possible. The way to move more volume of air and gas is through laminar or smooth flow. I do not want turbulence in the intake tract in order to deliver a higher volume of air and gas into the combustion chamber via smooth flow.
2. Fuel delivery also affects polishing decisions.

Delphi electronic fuel injection squirts gas towards the backs of the intake valves.

1. A carburetor begins mixing gas with the air in the venturi before the intake valve.
2. Therefore, a carbureted hemi-head (Knuck, Pan, Shovel or Ironhead XL) will want an unpolished intake tract.
3. A carbureted Evo and especially a Twin Cam will want a smoother intake tract.
4. A Delphi EFI Twin Cam will want the smoothest intake tract of the three examples given because the intake ports move only air. Smooth surfaces help flow the air in laminar layers as fast as possible.
5. I don't think there is much point in performancing a bike with Magneti-Marelli EFI (1995 to 2001) as this induction system is too small and inefficient.

There will be lots more on this in Volume II: *Performancing the Twin Cam.*

Rough Port Surfaces Have Little Effect on Turbulence

Let's get back to the river, which will demonstrate that a rough intake tract really doesn't have much effect on mixture anyway. It does have some, but not the amount one might think.

The water flowing on the riverbanks or river bottom may have some minor turbulence as it interacts with the rock or sand. This turbulence, if there is any, does not transfer very far, if at all, into the main stream of water movement. The same is true of the intake-head-port walls affecting air/gas mixture. There is some mixing taking place where the interaction occurs, but it does not affect the main body of air.

Interestingly, this also applies to oil flowing through oil cooler. Only the outside layer in contact with the channel wall cools. The inside oil in the center-flow does not and retains all the heat. In this case, I want a turbulator effect to occur. I will wisely choose an oil cooler like those designed by Jagg (www.jagg.com). The inside passage of these oil coolers have obstructions built in to turbulate and mix the oil so that all of the oil has an opportunity to dissipate or reject its heat. However, most oil coolers lack this simple and effective mechanism.

Let's return to head flow. I want as much air as possible flowing though the ports.

1. The least turbulence promotes the maximum flow, which has smooth and laminar characteristics.
2. Furthermore, I want as much turbulence as is possible inside the combustion chambers.
3. Squish bands surrounding a smaller combustion chamber produces the turbulence required for a high percentage of burn. The more turbulence in the combustion chamber, the better the mixture will be in correct proportions. This leads to more combustion that produces engine efficiencies, fewer emissions, and more horsepower as a very welcome by-product.

Lighter Valve Train

Valves and guides are thin stem since circa-2005. Traditionally, the valve stems on Harley-Davidson Big Twins are ⅜"-diameter. The stem diameter now reduces to $^5/_{16}$".

Sportsters made this move a long time ago. Usually, the XL has been ahead of Big Twins in introducing superior mechanical improvements. Performance builders have long replaced the fatter ⅜" stemmed valves and guides with thinner ones like those provided by Manley (www.manleyperf.com).

This was an important advance since the valves obviously become lighter. Valve trains in pushrod-operated engines like all modern Harley's except the V-Rod, are heavy affairs to move up and down with speed as in rpm. *Their weight limits their rpm capabilities.*

Overhead cams like those used in the V-Rod that actuate the valves directly are capable of high rpm.

Anytime the valve train lightens:

The engine will be capable of slightly higher rpm and therefore more power.

1. There will also be the added advantage of increased parts longevity.
2. A lighter valve train requires less valve spring-seat pressure to return the valves to their seats as the commanding valve lobe rotates to a lower position. This relieves pressure on the valve train increasing parts longevity.

TC96, TC103, CVO 110 Head Flow

One of the principle areas I address when porting TC88 heads is a severe overhang of the valve seat relative to the head port. On the 2007-to-present models, valve seats matching the head ports are improved from the 1999-2006 Twin Cams. While there is better matching of the seat, sometimes there is still some overhang. This needs to be radiused to increase flow.

Newton and Bernoulli's Laws Applied to the Twin Cam Head Ports

Another improvement to the reworked 2007-and-later head castings is that a restrictive-to-flow curvature on the inside of the turning exhaust port has been eliminated with the over- sizing of the whole port. The port progressively narrows down to the valve seat. This narrowing down will increase flow as explained by physics, namely Bernoulli's Principle. A fluid or gas moving from a larger volume space to a smaller one must speed up. The same amount of fluid or gas will move through the narrowing in the same period of time because of the relentless pressure from behind. This pressure difference will result in a net force, which by Newton's second law will cause an acceleration of the fluid…or, in this case air.

Some factory reps are alluding to the heads as reworked or massaged, but the casting looks to be of better quality. They may in fact be a new but similar looking head casting to the uninitiated from the 1999 to 2006 ones. It is nicer with smoother edges and more defined such as with oil cavities etc., although these aesthetic improvements do not affect anything mechanically; it is just visually better.

Tuliped Valves Assist in Head Flow

The exhaust valve (18085-05) is also more conducive to improved flow as it approaches a tapered tulip shape where the stem joins the top of the valve as opposed to the 1999 to 2005 more abrupt, flatter exhaust valve top.

The intake (18074-05) valve head also approaches a higher-flow tulip shape.

The valve guide (16465-06) has a shorter reach into the head, which is less obstructive to increased flow.

TC96, TC103, CVO 110 Head Port Size Increases over the TC88

I measured some 1999 to 2006 earlier exhaust head ports and found an average approximate diameter of 1.330"; this varies from head to head. The new head is about 1.510". This increase in size is huge as thousandths of an inch are equivalent to miles inside an engine.

Intake ports are pretty much the same size but a noticeable, and much improved difference, is that the seat edges and casting they fit into have actually, been machined to mate more correctly on the heads. However, this varies from head to head but a big improvement nonetheless.

The intake port shape is, again superior to previous Twin Cams, allowing for enhanced intake air flow. The port curvature is gentler and not as abrupt when changing course, allowing smoother flow.

Manifold Changes

Changed intake manifold (26993-06) flanges give better angling of the manifold aperture relative to the port it serves; the same flange serves both heads. In keeping with this, the actual flange mounting holes in the head itself are now equidistant from each other and the port-center. Earlier heads use (27009-86A and 27010-86A) front and rear flanges that mount to holes in the head that are offset and not equidistant. This, combined with the new injector angle of 25^0 from the previous 8^0-injector angle, serves to help increase flow of air and fuel delivery.

The heads still need porting and polishing to up the horsepower, which has not increased substantially from the Twin Cam 88 to the Twin Cam 96, even with eight more cubic inches and higher compression.

However, the head is an improvement over what went before. Installing 2007 TC96 heads on earlier 1999 to 2006 engines will result in much improved performance. It is just that it is not as much performance as could be gained by massaging them further. It is better to use superior aftermarket heads if deciding to go to the trouble and expense of replacing heads.

In conclusion, engine efficiency and resultant power are all about air. Gasoline cannot burn unless mixed in correct proportion with the oxygen found in air. If wanting both the TC88 and the TC96 to achieve maximum efficiency and to release suppressed horsepower, air flow capabilities need to improve for all Twin Cam heads, no matter the engine they serve.

CHAPTER VII

Retrofitting the Twin Cam Engine into Old Style Frames

Many longtime riders of custom Harley's in the early Twin Cam years were consumed with the past and sought to retrofit the new Twin Cam engine into the old-style Evolution frames.

The rubbermount Twin Cam 88A Dynas and FLT touring models and the counterbalanced TC88B Softail model engines become integral with their transmissions. They buttress each other and bolt together.

Softail vibration cancels internally, with counterbalancers fore and aft of the flywheel assembly. This changes the length of the bottom end on the right side with a knuckle at either end. Furthermore, Twin Cam Softail models are missing the traditional center downtube in their frames. The transmission attaches as one with the engine the same as with TC88A models. However, the transmission now becomes the de facto frame member. The frame actually bolts to the top of the transmission. Used forever with other brand motorcycles, this is a first for traditional Harley's. This methodology incorporates the engine and/or transmission as a structural mounting component.

Neither Twin Cam A nor B engines will fit into Softail style five-speed 1986 to 1999 frames when using the Twin Cam transmission. This also applies to rigid and old-style FL as well as some early Evo swingarm frames. The reasons are threefold:

The Twin Cam front side transmission box bolts firmly and rigidly to the engine rear, approaching unit construction. This is unlike Evolution or earlier model Harley's where the engine and transmission mount separately and independently.

1. The transmission internals have pretty much stayed the same from 1980 to 2006 with mainshaft changes in 1984, 1990, and 1991 along with other minor, but important, changes over the years. However, the transmission box also known as the *housing* is definitely a new design. The traditional Harley frame center downtube on the 2000 Softail has been partially removed and redesigned to accommodate this new unit construction transmission to engine arrangement.
2. The Twin Cam 88 engines are offset a full quarter-inch to the left (primary side). This necessitates a quarter-inch offset transmission and rear pulley spacer. I will explore this further later on.
3. There is no traditional rear frame mounting mechanism on the Twin Cam engine. As usual, the innovative Harley aftermarket comes to the rescue with simple and not so simple ways of using both traditional H-D frames and the Twin Cam 88A motors.

Simply Complicated

It is simple, really, in sort of a complicated way. Here is the plan. Use a Twin Cam 88A engine with a specially designed buttress adapter plate available from CCI, (PN 36995) or other suppliers like Mid USA, (PN 26055) to fit into a traditional center downtube frame. The rear engine buttress even allows the use of a stock Evolution top motor mount.

This kit will not work with the TC88B Beta engines because of the rear knuckle holding the aft balancer.

Next, use any 1989 to 1999 Softail-style five- or six-speed transmission and it's mating parts and the main mounting problem resolves. However, an offset component is required for both the transmission and the rear wheel pulley. Furthermore, I suggest a 1989 and later transmission because it uses the Harley Nippodenso starter motor (1989-to-present), which is far more reliable than its predecessor Hitachi and Prestolite starters.

The Offset Twin Cam Engine

Use of the Softail Evolution primary chaincase and enclosed parts works fine as do the Twin Cam Softail counterparts. Since TC88 motors have a built-in quarter-inch offset, use the chart below to figure out the required driveline parts.

This chart is for stock Evo or rigid frames that have no built-in offset.

Tire size	Primary spacer	Transmission Plate	Pulley spacer	Engine sprocket
130 to 160	Not necessary	¼" offset	¼" offset	Not necessary
170 to 180	¼" offset	½" offset	½" offset	Not necessary
190	½" offset	¾" offset	¾" offset	¼" offset
200	¾" offset	1" offset	1" offset	½" offset

I then had to modify the rear exhaust pipe by elongating it near the exhaust port of the engine. Actually, it is less expensive and far easier to make an aluminum extension for the exhaust port. This step will not be necessary if using a stock frame or a frame without wide rear tire offsets. It is a tenet of customizing that one change always leads to others.

Ain't I the Dumb Duck

My frame was custom made *with a built-in offset* for a 180-200-rear tire kit *using an Evolution engine.* I try not to do things backwards, but we were initially building my bike in 1999 with an Evolution engine until we saw the adapter buttress plate. Examining it, I became excited at its obvious ingenuity, quality, and strength.

Out came the Evo engine and in went a Twin Cam 88A engine. Now I had an offset that was a quarter inch too much. If the reader wants, a big rear tire on a shock-mounted frame with no exhaust modification work, then the use of a stock dimensional frame and a bolt on, wide-tire rear fork kit will furnish both a fatter tire and the Twin Cam Alpha engine.

The front pipe was okay on my particular bike, and my rear exhaust only required modification because I changed direction midstream. I had broken one of my own rules. Always think a project through from beginning to end before lifting a wrench or spending a dollar. I caution customers repeatedly about this. This modification would not be necessary had I thought everything out in advance.

TC88A Engine Installation in an Evolution Frame

A TC88 adapter plate adapts TC88A and TC96A motors only to Evolution-style frames, which include Softail and custom rigid frames. The kits include instructions and mounting hardware.

1. Bolt the adapter plate to the rear frame motor mount. This is straightforward and does not require instructions.
2. If any part of the rear-frame-to-engine mount protrudes in front of the adapter plate, grind the frame mount until it is flush with the plate. This was not a problem with my bike.
3. Re-bolt the plate to the engine in order to check for wrench clearance. There is an aperture in the plate. Sometimes there is a need to grind a bit out for easier wrench access. Do not grind more than three-eighths of an inch. We did this to my bike, and it is no big deal and does not weaken any part.
4. For installation of the Twin Cam engine, lay the adapter plate on the rear frame mount. Then install the two alignment dowels into the bottom of the rear flange of the motor. Slide the engine into the frame.
5. Now, lift the rear portion of the motor up into the adapter plate. The two dowels will keep the engine propped up. Obviously, two people are required for this procedure, as the engine weighs around 165 lbs.
6. Bolt the adapter plate to the back of the motor with the two longer bolts provided using flat and lock washers. Install the two shorter bolts to attach the plate to the rear frame mount.
7. As always, when mounting engines into frames, leave all the installed bolts loose until all align before tightening.
8. Install the front motor-mount bolts.
9. Snug all bolts ensuring a *comfortable fit without stressing any part.*
10. Align the inner primary with the engine and transmission.
11. As with any engine-to-frame mounting, it is very important that the primary bolts up comfortably with no stress at the bolt junctures, or else the primary tabs may break or crack.
12. If not, loosen engine-mount bolts and shim until there is a comfortable alignment fit all round.
13. Sequentially, tighten the engine bolts using red Loctite.
14. Sequentially, snug and tighten the primary bolts using blue Loctite.

Normally, mechanics use blue Loctite on all bolts and screws. However, Harley vibration requires the stronger red Loctite, normally reserved for permanent insertion of studs.

Bolting an engine in a frame requires that it fit snugly with no rocking before tightening the bolts. In other words, there cannot be a frame engine mount that is off-kilter; higher or lower than the others are. If this occurs and the engine is bolted down, the casings will be forced to twist to fit and will stress with consequences down the road. Many riders feel this is only a potential issue with aftermarket frames. Nothing could be further from the truth as all frames including Harley-Davidson ones must be checked and sometimes shimmed.

Apply the above fitment guidelines to the top motor mount, gas tanks, exhausts etc. The same rules listed for engine-to-frame fitment also apply throughout the bike. Any stressed part will weaken and break over time.

Wiring and Electrical

I cannot believe it, but I did not think this one through, either; the dumb duck was having a relapse from normal behavior. Please feel free to benefit from my lack of forward thinking, maybe I had the flu or fell in love or something. I guess my only excuse is that we had mocked the bike up with an Evolution engine, which I had planned on using. I even had painted the bike when my main man, Steve said, "Hey boss, look! I betcha we can mount a Twin Cam engine in here." "Far out!" said I. "Let's do it."

The TC88A engine we were using was purchased through a Harley dealer. It is missing a few components, though. I will list them later on.

If purchasing the engine at a swap meet or from a wrecker, make sure that the engine management system is included. The TC88 electrical sensors cannot be bypassed at the time of writing in 2000 unless, of course, one wants to convert to a dinosaur mechanical point's ignition.

Hooking up the engine management system properly is essential or the engine will not run. This system, which in simpler terms is a sophisticated ignition that makes the spark plug ignite the fuel at just the right time, requires mounting the following sensors in working order or else the engine will not fire or will run poorly.

1. The manifold absolute pressure (MAP) sensor (32316-99) on top of the manifold feeds an electrical pulse to the computer's electronic control module (ECM) for carbureted models and 2007-to-present Delphi EFI models, to determine whether the engine is under load or not. This information will determine whether the ignition timing (when the spark plug goes off), should be advanced or retarded. As piston speeds increase, so does timing advance. Conversely, ignition retards when the pistons slow down. This is necessary to compensate for combustion lag time. The air/gas mixture requires enough time to ignite and fully burn to create pressure on the downward power stroke's descending piston at the most opportune time.
2. The bank angle sensor (32495-98) with a 55-degree angle shut-off mode for carbureted, Magneti-Marelli EFI, and Delphi EFI (TLE/TLEU sidecar only), will protect your Twin Cam if it falls over. The engine management system will shut down the engine in order to protect it.
3. The flywheel or crank position sensor (32497-99 Magneti-Marelli EFI and carbureted; 32789-00/32707-01C for Delphi EFI) determines flywheel rotation position. This will in turn determine the position of the ascending and descending pistons. Correct ignition timing depends on piston position and speed.
4. The cam position sensor (32496-99) in 1999 to 2001 carbureted and Magneti-Marelli engines monitors the rotating camshaft cam lobe positions to determine when their corresponding valves are going to open and shut. This sensor provides very necessary information for the engine management system to determine ignition timing in 1999 and 2000 Twin Cams.
5. The Manifold Pressure + Temperature: TMAP sensor (32319-07) is required for 2007-to-present Delphi EFI models.
6. The Barometric: BARO sensor (32424-98) is required for 1999 to 2001 Magneti-Marelli EFI models.

7. The Throttle Position: TP sensor is required for Magneti-Marelli EFI models (27271-95) and for Delphi EFI models (27629-01/27659-06).
8. The Intake Air Temperature: IAT sensor is required for Magneti-Marelli EFI models (27270-95) and for Delphi EFI models (27270-95/27381-06).
9. The Engine Temperature: ET sensor (32446-99) is required for Magneti-Marelli EFI models and for Delphi EFI models.
10. The Oxygen (O_2) Sensors (27719-07; 27683-07) is required for 2007-to-present Delphi EFI closed loop EFI.
11. Finally, the Twist Grip (fly-by-wire) sensor (32305-08) is required for 2008-to-present Delphi EFI models.

People like me have been extolling the virtues of the Twin Cam 88 engine design for some time now. However, many have ignored or not been aware of what Harley has done on the electrical end of things. This is sophisticated and very good stuff. As always, we must adapt and learn.

I digress again; a bonus is that the TC88, TC96, TC103, and CVO 110 engines are single fire, which means that the spark plug goes off once every four cycles near the end of the compression stroke. Once again, combustion lag dictates the spark firing on the seemingly wrong stroke. However, everything is just getting set up for optimal action to occur on the next cycle, the power stroke. Combustion lag is the time it takes for gas to start burning. Mechanical lag is the time it takes for valves to get fully moving and for pistons to change direction at top-dead-center of their strokes. Single fire is a bonus for engine efficiency, slight vibration reduction, and a mild performance increase.

On previous carbureted Evo, Shovel, Pan, Knucklehead, and Sportster models, the ignition is dual fire. The plug fires twice in this system once at the end of the compression stroke as it should and then as an additional wasted spark during the exhaust stroke.

The supplementary electrical list you must acquire and mount is as follows. Where possible, the astute consumer might as well use Screamin' Eagle or aftermarket such as Crane (www.sscycle.com) performance ignition-system parts. Crane Cams went out of business in 2009. S&S Cycles, Inc. acquired some of their proprietary parts.

Therefore, if you are buying your engine at a swap meet here is the Harley part numbers and descriptions of what you will want to acquire for a 1999 engine. The parts will be much the same for subsequent year engines but may have different or upgraded parts numbers.

1. 32435-99 ignition harness.
2. 74518-99 voltage regulator.
3. 32316-99 manifold air MAP sensor.
4. 38723-99 retaining clip for the manifold MAP sensor.
5. 11291 seal, mounting manifold MAP sensor.
6. 31960-99 spark plug cables…the ends are different from previous plug cables. The coil end is now a male fitting instead of a female one.
7. 32495-98 switch, bank angle sensor…55-degree tilt and the bike will shut off.
8. 31710-99 S.E. 6200 rpm carbureted coil and module for stock compression ratio.
9. 27613-99 manifold…old flanges (Evolution) will work. The Twin Cam manifold while it appears to be the same is wider than the Evo one so it is better to get one of these.
10. A carburetor and air breather assembly.

Electronic fuel injection (EFI) engines will require some different parts for the conversion. Consult your manual for year and model.

An aftermarket ¼" offset transmission base plate and pulley offset spacer will also be necessary. These are readily accessible, inexpensive, and easy to install. Other conversion kits are becoming available monthly as I write this in 2000. Some of them use a completely new frame setup with adaptor plates. By the time the first version of this book published in 2007, some, but not all, of these adapter kits will have become obsolete as Harley riders forget the past and move on.

Many aftermarket engine producers like S&S currently offer big-inch Twin Cam configurations in specialized engine casings that incorporate the stock H-D abutment methodology or the Evolution rear mount system. It just gets easier all the time.

Chapter VIII

Twin Cam Fuel Delivery

The Twin Cam engine uses only one carburetor made by a subsidiary of Honda and two electronic fuel injection (EFI) systems from 1999-to-present. They are the CV Kehein carburetor, Magneti-Marelli EFI and Delphi EFI.

1. The CV Kehein carburetor: 1989 to 2006 continued use from the Evolution onto some model Twin Cams and the Evolution Sportster until the end of 2006 when all models began or continued use of the Delphi electronic fuel injection. There is some discrepancy on the CV Kehein first year of use but certainly dominated beginning in 1990 long before the advent of the Twin Cam in 1999.
2. The Magneti-Marelli EFI: 1995 to 2001 continued use on some Touring FLT model Twin Cams until the end of 2001 when succeeded by Delphi EFI in 2002.
3. Magneti-Marelli EFI never saw use on Dyna Glide or Softail models.
4. Delphi EFI began use on Softail Twin Cams in 2001. All first year 2000 Twin Cam Softail models used CV Kehein carburetion.
5. Dyna Glide models used CV Kehein carburetion exclusively until the end of 2003. Delphi EFI introduced on some Dyna models in 2004. In 2005, all Dyna models switch to Delphi EFI.

Before I describe the three fuel induction methodologies used on different year Twin Cams, I am going to discuss fuel; octane, ethanol, and methanol mixed in with pump gasoline and reformulated gasoline.

Gasoline for the Twin Cam

It is advisable to run at least an 87-octane or higher preferably at least a 91-octane, quality leaded or unleaded gasoline for all Twin Cam motorcycles 1999-to-present. Be aware that lead is a dirty but effective Octane that can foul spark plugs, wreck catalytic converters, deteriorate muffler internals and will dirty oil faster than unleaded fuels. Higher compression bikes require a higher Octane gasoline. The Twin Cam 88 has higher compression than Evolution models and therefore, requires a higher octane-rated gasoline.

It doesn't end here because Harley-Davidson progressively increases compression ratios with newer Twin Cam engine designs and models. Hard acceleration as well as higher ambient temperatures will also increase the chance of engine detonation and thus the need for a higher Octane fuel.

Twin Cam Compression Ratios

Compression Ratio	Model	Displacement
9.0:1	All TC 88c.i models 1999 to 2006	88c.i
9.2:1	All TC 96c.i models 2007-to-present	96c.i
9.6:1	FLHTCUG Tri Glide Ultra and FLHXXX Street Glide Trikes	103c.i
9.7:1	FLHTK Electra Glide Ultra Limited	103c.i
9.15:1	CVO Screamin' Eagle models	110c.i

Some compression ratios change slightly in 2011.

Alcohol additives like methanol and ethanol can harm rubber carburetor/EFI components depending on the percentage blended. Modern Harley-Davidson's are designed to run on unleaded gasoline. Unleaded gas is less harmful to the environment. Leaded fuel uses lead as an excellent but dirty environmental unfriendly Octane.

Always:

1. Use gas from national brands because it is more likely they adhere to standards. I don't like and hesitate to make this recommendation because it squeezes out smaller players with much integrity. However, I don't know what else to say because there are a few small unscrupulous gas stations out to increase profit that will dilute proper mix gasoline with less expensive substances like Benzene that are both harmful to the environment, gas tank sealant, and/or rubber components. I have been a victim of this so I know it happens.
2. Purchase gas from a busy gas station because they get fresh deliveries more often.
3. Water and sediment will not get a chance to build up.
    a) Fuel does not have a chance of separating into component parts. The alcohols can separate from the gasoline over time.

Methanol

It is a *not* good idea to use methanol mixed gasoline at all no matter how low the content; plus Harley-Davidson says not to use it. Methanol may cause hard starting and rough running. It will damage fuel system components especially rubber seals. If you are in the middle of nowhere and this is all that is available, use it until getting to another gas station with the proper fuel for your Harley. Half-a-tank will not hurt in an emergency but fill up and mix in proper fuel as soon as possible.

Reformulated Gasoline

It is okay to use *oxygenate* reformulated (RFG) gasoline's. RFG gas burns cleaner than normal pump gasoline. If your bike reacts to one brand of RFG, switch to another.

Ethanol

Ethanol content up to 10% ethanol and 90% unleaded gas is okay. Avoid higher percentages of ethanol unless in an emergency situation. This is getting tricky as some gas stations now have ethanol mixed gas in a 15%/85% ratio. I am sure H-D is and will adapt to this scenario.

Inanimate H-D Schizophrenia

I know this is going to sound stupid but Harley-Davidson's have differing personalities. If your bike does not run as well on one gasoline or spark plugs then switch to another brand. It is amazing how this works.

The H-D Brain and Ethanol

The engine management system's ECM (electronic control module) also known as an ECU (electronic control unit) or ICU (ignition control unit) is not programmed to use a different fuel mix like 15% ethanol and 85% gasoline. How can the bike run properly if the brain receives information and gives instructions for burning a different gasoline composition than what it is programmed for?

- The reason is that ethanol burns at a different optimal air-fuel-ratio than gasoline so poor running can easily result.
- Gas mileage will also reduce with a higher percentage of ethanol because it produces less heat measured in BTU's (British Thermal Units).
- Ethanol fuel may seem less expensive but it makes less heat energy. More ethanol will need to burn to produce equal energy to the burning of a smaller amount of gasoline.

British Thermal Units and Related Heat Measurement

Heat measures in BTU's as well as a number of seemingly unrelated measurements. A BTU defines as the amount of heat (energy) required raising 1lb of water 1° F. A U.S. gallon of gasoline contains about 118,000 BTU's.

It all started with James Watt of light-bulb wattage fame who was trying to figure out how much work a small coal mine work horse could accomplish. He measured this and arbitrarily raised the amount for a mythical larger horse to determine the amount of work performed with a *horsepower.* Horsepower has equivalents in wattage and yes, the calories of energy we consume in food as well as a host of other familiar but seemingly unrelated measurements of work and energy, which may seem different but are all the same. I quote Tracy Martin from *How it Works, The Gas We Pass* in May 2010 issue *American Iron Magazine.* "…a burning match…produce(s) about one BTU. Another way to measure the amount of energy stored in a gallon of gasoline is to determine how much electricity it produces in Kilowatts (1000's of watts). One gallon of gas is equivalent to about 36 kilowatt-hours. So, if you left a 1000 watt space heater on continuously for 36 hours, it would consume about the same amount of energy available in one gallon of fuel. Calories yes, the same ones we eat, are also units used to measure energy stored in gasoline. If you ride to McDonald's for lunch and manage to eat 114 hamburgers, you'd have consumed 31,000 calories or the amount of energy in a gallon of gas."

High Concentrations of Ethanol are Harmful to Your Harley

It will not hurt your engine to temporarily burn a tank of high percentage ethanol relative to gasoline if that is all that is available but use it quickly and refill with proper gasoline as soon as possible. A high percentage of ethanol has other problematic issues that will affect your Harley-Davidson over time.

1. The first of which, it is corrosive to sheet metal. Continued use of ethanol requires the use of stainless steel gas tanks.
2. Secondly, it will also peel off tank sealer inside the tank, which is a nightmare to repair as the sediment constantly bungs up fuel filters and smaller orifices.
3. Thirdly, ethanol attacks rubber gas lines and destroys their usefulness.
4. The rubber used for sealing manifolds and the O-rings found inside carburetors and EFI induction will expand and go wonky leaving fuel to leak and excess air to enter and lean out the engine.
5. Finally, high concentrations of ethanol are caustic attacking the aluminum in EFI induction throats and carburetor bodies.

Viton rubber-based manufactured seals, O-rings and fuel line will withstand ethanol much longer. Use fuel line with a SAE (Society of Automotive Engineers) rating of SAE J1527.

Read your H-D manual to determine the allowable percentage amount of ethanol in gasoline for year and model Harley Davidson. However, all Twin Cam models should use 87-octane or higher.

Ethanol and Food Shortages

Food shortages, particularly in the third world and emerging economies are in conflict with incomes that are more lucrative for farmers growing the grains for ethanol production.

Defenders say that rising energy prices and fertilizer costs are more of a factor with rising food costs with ethanol only contributing 15% to food costs.

- Furthermore, others feel that lobbyists in the oil industry are spreading false rumors and misinformation about ethanol to defeat its usage in gasoline.
- These ethanol supporters say that the protein and other nutrients are mere byproducts; that only the starch in the plant fiber is useful for ethanol production.
- Still other defenders of ethanol point out that this less expensive product keeps the more expensive oil-based gasoline in check; that gas would cost much more without the inclusion of ethanol.

E10, E15, E20, and E85

This nomenclature should always appear on the gas pump. Twin Cams are now designed to run on E10, which designates 10% ethanol and 90% gasoline. E15 and E20 fuels have 15% and 20% ethanol respectively with the remainder being gasoline. However, increasing amounts of ethanol decreases available heat energy to propel the motorcycle. There are fewer BTU's (British Thermal Units) in ethanol, which causes a slight decrease in power as well as fuel economy than if using 100% gasoline. Ethanol produces approximately 76,000 BTU's of heat as opposed to about 118,000 BTU's for gasoline. Now for the mind twister:

- To gain the same power as gasoline, a larger amount of ethanol is required.
- Pure ethanol has an Octane rating of close to 114. Therefore, ethanol allows the use of higher compression, which of course, generates more power.
- Gasoline can usually accommodate from 8:1 compression up to about 10:1 compression depending on head design and other factors. Pure ethanol (E100) can easily accommodate 13:1 compression or more depending again, on head design and other factors. However, E100 cannot be used in a traditional gasoline design engine.

E85 can be found at some pumps. It is another situation altogether as it is 85% ethanol and only 15% gasoline. A gasoline-design engine must be converted or designed specifically for use with this clean fuel. *Do not use E85 fuel in a Harley-Davidson.*

The Ethanol Advantage

The advantage of the alcohols like ethanol is they burn cleanly. Ethanol is a renewable resource in that it is made from plant starch or fiber quite unlike finite fossil fuels that require extreme compression and millions of years to form. Ethanol is a safe Octane enhancement.

Octane

Octane prevents gas explosions and encourages burning at a defined rate. The discovery of Octane was one of the great advances in engine technology during the early 1900's. There are many different Octane substances or elements, the best early example is lead, which controls the rate of burn. Before Octane, haphazard-detonating explosions destructively caused the first engines to hack along with much inefficiency. Octane has the ability to stop chaotic explosions and bring order to the combustion chamber. Octane is a very specific compound; more correctly various Octanes comprise of differing chemical compounds of differing chemicals in use for comparative testing of detonation resistance of other fuels. Gasoline is a complex mixture of many chemicals. Chemical components add and delete to enhance the Octane rating.

Tetraethyl Lead was the old and easy way; now it is a lot more complex. Lead is an excellent Octane but is also corrosive to the internal engine parts including spark plugs and exhaust/ muffler internals. Some Octane's are oxygenates (MTBE and all the alcohols) that also lean the mixture and diminish power unless gas refiners compensate for them. Enhanced Octane reduces detonation harm inside the engine but many times produces harm to the environment and to us.

Lead, for example causes mental retardation and learning disabilities in children. It does so to a lesser extent with adults. The reason is that children will put substances in their mouths at one time or another that adults will not. A very dangerous quality is that lead tastes good. Have you ever sucked on a lead pencil while thinking? Back in the day, engine exhaust left lead residue everywhere on the ground and in the soil where children play.

- Successive Octane's did not necessarily wreak havoc with children's brains but they did cause cancer with all that exhaust permeating the air with silent debilitating and sometimes-carcinogenic killing fumes.

The Combustion Chamber Flame Front and Percentage of Burn

Octane causes fuel to burn at a predetermined rate. An Octane enhancer discourages unwarranted and unwanted explosions. How long it takes a flame front to travel across a combustion chamber with controlling Octane allows the engine designer and tuner alike to advance ignition timing or retard it. The spark can ignite the fuel at the most auspicious time for maximum fuel burning known as the *percentage of burn,* thus creating maximum controlled heat.

Combustion Lag

Some of the main factors determining ignition timing are:

1. Rate of burn.
2. Piston speed.
3. Cylinder diameter.
4. Cam timing, which is when the valves open and close.
5. Dual or single spark plugs.

Thus, the complex blueprint of valves opening and closing on previous and succeeding engine strokes has much to do with mechanical lag time. The spark ignition occurring before a compressing piston reaches the top of its stroke is all about combustion lag.

Combustion lag is the time it takes to get gas burning at a set rate.

1. Mechanical lag time is the time it takes for parts to get moving…after all, valves have to open and close.

Gasoline Additive Effects on a Harley-Davidson

I will be concentrating on rubber components in the fuel induction system and the effect that ethanol and methanol may have on them.

MTBE Oxygenate Gasoline Additive

MTBE has been used in *low levels*, which is supposedly okay for your Harley-Davidson since 1979 to replace lead as a very effective octane enhancer but a dirty, unhealthy additive. Octane is necessary in gasoline to produce a controlled burn in the combustion chamber as opposed to uncontrolled explosions known by various names such as detonation, spark knock and pinging.

In 1992, in response to the 1990 Clean Air Act Amendments by Congress, the use of MTBE has increased in concentration in some gasolines. MTBE is the acronym for methyl tertiary-butyl ether ($C_5H_{12}O$). This oxygenate compound produced by reacting methanol with isobutylene is an octane enhancer. MTBE is an oxygenate, which raises the oxygen content of gasoline, which will make it burn better. Oxygen assists the gasoline in burning more completely, both producing more energy but also reducing harmful emissions.

Sulfur content in gasoline is a big problem because of its polluting nature as is Benzene an aromatic, which is another type of oxygenate. Benzene is not healthy for humans. The oxygen in MTBE dilutes or replaces sulfur and benzene content. MTBE is flammable and volatile and will mix easily with water that will get pumped into a gas tank from the gas station reservoir. This is a good thing since moisture will burn off. However, methanol can have an adverse effect on certain rubber compounds like those used in Harley-Davidson Twin Cam motorcycles, particularly manifold rubbers and internal carburetor rubber parts, and the rubber used in the diaphragm of the vacuum operated petcock.

Reformulated Gasoline and Vehicle Performance

"The 1990 Clean Air Act (Act) requires the Environmental Protection Agency (EPA) to issue regulations that would require gasoline to be "reformulated" so as to result in significant reductions in vehicle emissions of ozone-forming and toxic air pollutants....This cleaner gasoline is called reformulated gasoline (RFG). RFG is required for use in nine major metropolitan areas of the United States with the worst ozone air pollution problems. In addition, several other areas with ozone levels exceeding the public health standard have voluntarily chosen to use RFG.

Reformulated gasoline will have no adverse effects on vehicle performance or the durability of engine and fuel system components. In fact, the nation's major auto manufacturers support – even recommend – the use of RFG." [1] (This of course, is not true for Harley-Davidson's as RFG gasoline may or may not have consequences to proper functioning rubber components in the fuel supply system depending on ethanol or other substance content). "There are hundreds of different formulations for making gasoline. And the ingredients used to make RFG are no different from ingredients used to make conventional gasoline. RFG and conventional gasoline differ only in the levels at which the ingredients are used, thereby reducing the use of the substances that contribute to air pollution. However, like other gasoline's, RFG is formulated to burn in a manner that will suit the power requirements of the vehicles in which it is used. While vehicle performance has always been considered when choosing a fuel formulation, emissions performance of fuel formulations had generally not been considered until the Clean Air Act mandated reductions in vehicle emissions. Now, with reformulated gasoline, emissions performance is considered along with the other requirements to produce high quality gasoline. This means that in terms of RFG's affect on drivability, vehicle owners should notice little change in vehicle performance but harmful emissions will be reduced dramatically.

In order to understand why RFG should provide the same performance characteristics but better emissions properties when compared to conventional gasoline, it is important to note how it differs and how it is the same as other gasoline's:

1. RFG has lower levels of certain compounds that contribute to air pollution.
2. RFG will not evaporate as easily as conventional gasoline.
3. RFG will contain *chemical oxygen* (oxygenates). [1]

Some Oxygenates Create Wonky Rubber

As I will say many times, the rubber in H-D carburetors, EFI induction throats, and manifold seals cannot withstand concentrates of methanol or ethanol. Non-oxygenated gasoline co-existed easily for years of problem free use with the rubber O-rings and seals. The rubber components will also tolerate low levels of oxygenates, usually less than ten percent. However, higher percentages will certainly be problematic and distort crucial seals.

Sometimes, vendor supplies of component parts to Harley-Davidson and other manufacturers will not be up to the task at hand. Responsible manufacturers like the Motor Company will institute mechanical and safety recalls in these circumstances.

H-D dealers are required to perform every recall service to any bikes still in inventory before selling them, which is logical but apparently needs to be said. The dealers also have to perform the service whether the Harley-Davidson was purchased off them or not. I praise Harley-Davidson for stipulating this because in my personal experience *some* highly successful and busy but arrogant dealers would turn away warranty or safety recall work if the bike were purchased elsewhere to punish the customer. Harley Davidson does not tolerate this type of behaviour with a safety issue and good for them.

For example, one recall involves replacing the original rubber diaphragm assembly in the CV carburetor with a replacement one contained in Recall Code 088, part number 93797, more tolerant to this type of 10% ethanol oxygenated gasoline. This oxygenation content in modern gasoline will be an ongoing problem as almost every H-D manual specifies not to use any gasoline with an ethanol content of more than 10%. There is further advice not to use a gasoline with any methanol. H-D also says that reformulated gas is *now* safe to use. However, the Motor Company advises that if your bike has an adverse response to a particular gasoline in terms of starting, running quality or mileage, to switch brands or try one with a higher octane rating. [2]

S&S Cycle, Inc. EFI can use 20% Ethanol Fuel

S&S is the venerable, progressive aftermarket high performance king. S&S has developed their proprietary closed loop fuel injection system and electronic control module. Closed loop EFI uses oxygen 0_2 sensors that *read* the exhaust composition in the exhaust pipe(s).

All 1995 to 2000 Evolution and Twin Cam EFI systems are Magneti-Marelli open loop systems. Some touring models in 2001 also utilize MM EFI. There are four main fuel dimensions to EFI delivery:

1. Cold idle, where extra fuel increases rpm to warm up the engine; this is a load situation.
2. Hot idle, where the idle returns to a lower rpm for normal running in a no-load position.
3. Cruise, rpm stays the same or gradually increases in a no-load circumstance,
4. Acceleration, where rpm increases in a load situation.

The main difference between open loop and closed loop is that the air-fuel-ratio in a closed loop system will be at 14.7:1 parts air to one part gas during hot idle and cruise no-load situations. Cold idle and acceleration increase engine load and must use a richer gas-to-air valuation anywhere from about 13.0:1 up to 14.7:1 Stoichiometric. The 14.7:1 ratio is called Stoichiometric, which for gasoline produces the most complete combustion possible thereby increasing gas mileage and decreasing harmful emissions. Open loop EFI like the H-D Magneti-Marelli system and early Delphi EFI does not approach Stoichiometric air-fuel-ratios but runs at richer ratios throughout the rpm range especially during hot idle and cruise situations as determined by fixed ECM electronic control module settings.

In an S&S newsletter issued on August 1, 2006, the company addresses ethanol-blended fuels with an article titled Closed Loop Fuel Injection and Ethanol Blended Fuels. I quote "S&S Cycle Inc. has completed testing of its Closed Loop Variable Fuel Injection system with E20 blended fuel (20% ethanol). The results of this test show that the system adapts to the fuel to achieve best performance and drivability with the reduced energy content of alcohol blended fuel, and all components in the system are impervious to the alcohol in the fuel. The *Proven Performance®* S&S Closed Loop Variable Fuel Injection system determines the air/fuel ratio by measuring the oxygen in the exhaust. The electronic control module then adjusts the injector opening time to compensate for the ethanol content of the fuel, minimizing ethanol's effect on performance. The addition of ethanol to fuel blends being sold to retail customers has been a problem for many engine management systems and carbureted vehicles without closed loop fuel control capability. The S&S Closed Loop Variable Fuel Injection system will easily accommodate the E10 (10% ethanol) and E20 (20% ethanol) blends that have been, or will be, mandated by some government jurisdictions....Engine management systems and carburetors without provisions for ethanol require recalibration or re-jetting to run properly on blended fuels. This is acceptable if the rider lives in an area where the fuel is all blended the same, but riding over distances may take the rider into a region where the fuel is blended with less or more ethanol content, resulting in poor performance and drivability...S&S has been actively working on emissions and regulatory projects since we started selling engines," said Scott Sjovall, VP Product Development for S&S Cycle. "Our Closed Loop Variable Fuel Injection system is a great example of how projects can be both environmentally friendly and performance enhancing. The closed loop system works constantly to keep your engine running at peak efficiency – resulting in more power and lower emissions even with changing fuel and weather conditions. With our system, E20 is no problem...During testing, S&S determined that the Closed Loop Variable Fuel Injection system will allow the engine to run on E20 without a loss of horsepower or torque. Fuel economy tests showed a reduction in fuel mileage of about 4.0 % due to the reduced energy content of the fuel." [3]

Cold Weather Additive

Icing is a condition that I have experienced on a Harley-Davidson only once. It was on my Shovelhead chopper in the seventies. I was using a fad at the time, an automotive SU carburetor, which necessitated a pretty long manifold for gas tank clearancing. It was a hot humid summer day. I pulled over on the highway for a smoke, looked down and couldn't believe my eyes. There was dense ice up to ¾" thick around the manifold packed so hard it was difficult to chip off in the hot sun. I never did figure that incident out as the bike still ran. It would have run better without ice but it got me to where I was going. The ice mysteriously disappeared under its own volition.

Icing is a condition that usually occurs with low ambient temperatures combining with high humidity. The symptoms other than a build-up of ice are erratic engine operation with a lowering of the idle rpm. The Motor Company developed a response to icing back in early 1992 with an additive known as Winter Fuel Conditioner (HD 99889-91). I am only discussing this subject out of interest because I am sure the reader will never need this conditioner. This additive is a *freezing point depressant.*

The fuel conditioner has a high flashpoint but will still ignite and burn in the combustion chamber. Flashpoint defines as the lowest temperature at which, a flammable liquid will ignite. The Winter Fuel Conditioner will ignite at 188^0 F (87^0 C), which compares with regular unleaded gasoline at -41^0 F (-43^0 C). The mix ratio, which I am sure you will never need, is .25 ounces per gallon of premium gasoline. I feel this procedure is a whole lotta hassle for something that will go away on its own.

Twin Cam Fuel Induction Systems

Year	Model	CV Kehein Carburetion	Magneti-Marelli EFI [A]	Delphi EFI [B]
1999	FLT	FLHT, FLHTC, FLHR, FLTR	FLHTCUI, FLHTCI, FLHRCI, FLTRI, Shiners [C]	NA
1999	Dyna	FXD, FXDX, FXDL, FXDWG, FXDS-CON	NA	NA
2000	FLT	FLHT, FLHTC, FLHR, FLTR, Shiners	FLHRI, FLHTCUI, FLHTCI, FLHRCI, FLTRI, FLTRSEI, Shiners	NA
2000	Softail	FXST, FLSTC, FLSTF, FLSTS, FXSTS, FXSTB, FXSTD	NA	NA
2000	Dyna	FXD, FXDX, FXDL, FXDWG, FXDS-CON	NA	NA
2001	FLT	FLHT, FLHTC, FLHR, FLTR,	FLHRI, FLHTCUI, FLHTCI, FLHRCI, FLTRI, FLTRSEI[2], Shiners	NA
2001	Softail	FXST, FLSTC, FLSTF, FLSTS, FXSTS, FXSTB, FXSTD	NA	FXSTI, FLSTCI, FLSTFI, FLSTSI, FXSTSI, FXSTBI, FXSTDI
2001	Dyna	FXD, FXDL, FXDWG, FXDX, FXDXT, FXDWGSE[2]	NA	NA
2002	FLT	FLHT, FLHTC, FLHR, FLTR	NA	FLHRI, FLHTCUI, FLHTCI, FLHRCI, FLTRI, FLHRSEI, Shiners
2002	Softail	FXST, FLSTC, FLSTF, FLSTS, FXSTS, FXSTB, FXSTD	NA	FXSTI, FLSTCI, FLSTFI, FLSTSI, FXSTSI, FXSTBI, FXSTDI
2002	Dyna	FXD, FXDL, FXDWG, FXDX, FXDXT, FXDWGSE[3]	NA	NA
2003	FLT	FLHT, FLHTC, FLHR, FLTR	NA	FLHRI, FLHTCUI, FLHTCI, FLHRCI, FLTRI, FLHTI, FLHRSEI[2], Shiners
2003	Softail	FXST, FLSTC, FLSTF, FLSTS, FXSTS, FXSTB, FXSTD	NA	FXSTI, FLSTCI, FLSTFI, FLSTSI, FXSTSI, FXSTBI, FXSTDI, FXSTDSE
2003	Dyna	FXD, FXDL, FXDWG, FXDX, FXDXT	NA	NA

2004	FLT	FLHT, FLHTC, FLHR, FLHRS	NA	FLHRI, FLHTCUI, FLHTCI, FLHRCI, FLTRI, FLHTI, FLHRSI, FLHTCSE, Shiners
2004	Softail	FXST, FLSTC, FLSTF, FXSTS, FXSTB, FXSTD, FXSTDSE[2]	NA	FXSTI, FLSTCI, FLSTFI, FXSTSI, FXSTBI, FXSTDI
2004	Dyna	FXD, FXDL, FXDWG, FXDX	NA	FXDI, FXDLI, FXDWGI, FXDXI
2005	FLT	FLHT, FLHTC, FLHR, FLHRS	NA	FLHRI, FLHTCUI, FLHTCI, FLHRCI, FLTRI, FLHTI, FLHRSI, FLHTCSE[2] Shiners
2005	Softail	FXST, FLSTC, FLSTF, FXSTS, FXSTD, FXSTB, FLSTN, FLSTSC	NA	FXSTI, FLSTCI, FXSTSI, FLSTFI, FXSTDI, FXSTBI, FLSTNI, FLSTCI, FLSTFSE, Shiners
2005	Dyna	FXD, FXDL, FXDX, FXDWG, FXDC	NA	FXDI, FXDXI, FXDLI, FXDWGI, FXDCI
2006	FLT	FLHT, FLHR, FLHRS FLHX	NA	FLHRI, FLHTCUI, FLHTCI, FLHRCI, FLTRI, FLHTI, FLHRSI, FLHXI, FLHTCUSE
2006	Softail	FXST, FLST, FLSTC, FLSTN, FXSTD, FXSTB, FLSTF, FLSTSC, FXSTS,	NA	FXSTI, FLSTI, FLSTCI, FLSTNI, FXSTDI, FXSTBI, FLSTFI, FLSTSCI, FXSTSI, FLSTFSE[2]
2006	Dyna	NA	NA	FXDI, FXDLI, FXDWGI, FXDCI, FXD35, FXDBI
2007 up	All	NA	NA	All [D]

Consult your manual for accurate representation of models and years. There are some specialty models only available in the USA or for other countries like Japan, Brazil, India, or the UK. Some countries may have specific specialty orders not available elsewhere. EFI versions of some carbureted models may not have worldwide distribution.

[A] Magneti-Marelli EFI: 1995 to 2001 continued use on Touring FLT model Twin Cams until the end of 2001 when succeeded by Delphi EFI. Neither the Dyna Glide nor the Softail lineup ever used MM EFI.

[B] Delphi EFI began use on Softail Twin Cams in 2001. First year 2000 Twin Cam Softail models used the CV carburetion exclusively. Touring FLT models began use of Delphi EFI in 2002. Dyna Glide models saw first use of EFI (Delphi) in 2004.

[C] Shrine Harley-Davidson motorcycles are special order for Shiners International best known for hospital charity work and their unique conventions and parades. The Shriners fraternity bases on fun, fellowship and the Masonic principles of brotherly love, relief, and truth. (www.shrinershq.org/Shrine)

[D] From EFI's inception in 1995 until the end of 2006, all model nomenclature denotes EFI equipped models with the suffix I for injected. If there is no suffix to designate an EFI model, it will be carbureted. In 2007, all models become injected and carburetion becomes obsolete. On 2007-to-present models, the suffix I is dropped. Therefore, the reader must be aware of the year before assuming whether a model is carbureted or injected while reading and interpreting model nomenclature. For example; a 2006 Harley-Davidson with nomenclature without a suffix I will be carbureted while 2007-and-later models will be fuel injected.

Fuel Tank Cleaning, Sealing, and Storage

Fuel Tank Cleaning

Harley-Davidson gas tanks are internally pre-treated at the factory to resist oxidation (rusting). However, if necessary to clean out sediment deposits, other types of chemical sludge, or if the internal treatment has not prevented rust then clean with the following procedure.

Drain the gas safely in a well-ventilated area into an approved storage gas receptacle. Over 35-years of daily mechanics, I have seen preventable fires, the majority of them occurring at campsites or on the road.

Donny's Blasts from the Past: Checking for Gas in the Tank

What I am about to describe is not an isolated incident as I have seen this happen numerous times in the old days when just about everyone smoked cigarettes. The chopper and Decker (touring bikes) riders of yesteryear did not have cell phones, credit cards, or carried flashlights. Motels were a rarity with most sleeping outside in sleeping bags or just lying beside a bonfire. Problem solving occurred on the spot because the rider was not proceeding with the ride until the bike would start and run. This meant the group was not leaving a brother-in-the-wind behind so everyone stayed until the down-bike was up and running.

Now, I have not seen this in recent years. Maybe it is because camping is not as common as it once was, the average IQ of H-D riders have increased, or there are too many conveniences like cell phones that present other options. On the other hand, I don't sleep out that much myself anymore, preferring a warm bed and a bar, so I may be missing the action.

Anyway, at night with a broken down ride, the first thing that should be checked is if there is gas in the tank. If I cannot see and I do not have a flashlight to visually observe gasoline though the gas cap bung; I simply grab the handlebars and shake the bike to hear the swish of gas.

However, some would pull out their trusty cigarette lighter, which was the old flint and wick style since the Bick was yet to be invented. Leaning over, the rider would pull the ever-present cigarette out of his mouth so he could get his eyeball down close to the gas cap bung to have a look-see. Flicking the flint roller on the lighter would provide the necessary illumination to determine visually if there was gas in the tank. One thing is for sure, there was evaporating, highly flammable fumes. Invariably, evaporate would ignite into a flash ball of fire.

So, if ever observing a grizzled old biker without eyelashes you will not have to ask why.

Cleaning the Tank

1. I first use very hot water and fill the tank, swish it around, and then drain. This will help cleanse the tank of evaporate and get rid of floating oxidation and/or sediment.
2. In a well-ventilated area, I will then put alleys, or other non-metallic balls, or pellets into the tank and shake vigorously while rotating the tank. I concentrate on the lower portions because loose sediment will gravitate to this location before coagulating or solidifying. Metallic ball bearings have the potential of sparking any evaporate although I have not personally seen this happen.
3. I now blow out the tank with compressed air to remove loosened debris. Avoid directing compressed air straight at the tank sealer as a whole new set of problems arises if it begins to separate from the tank.
4. Now, I use dish detergent and hot water to thoroughly wash and flush the tank.
5. Next, do the same with hot water. Hot water evaporates and dries more efficiently than cold water. We do not want water in the gasoline.
6. Lastly, blow out again. Do not assume the tank is clean because you cannot see anything. The dirt particulate size between the float needle and its seat that can hold a float open is sometimes invisible to the eye.

Fuel Tank Sealing

This is an irritating and time-consuming repair. Many service departments will simply replace the very expensive painted tank. I am a repair kind of a person that likes to save customers and myself money if possible. Removal of the material is laborious and painstaking.

Reseal the tank with a three-stage sealer. One such excellent product is from Kreem Products (www.kreemproducts.net). The 3-stage kit is available from most motorcycle distributors like Mid USA (PN 05419), CCI (PN 3991004), and local bike repair shops. Kreem also sells a 5-stage kit for problematic tanks that is available from their website. For the 3-stage kit that I normally use:

1. The first step is a cleaner.
2. The second etches the metal.
3. The third seals the inside of the gas tank(s).

The sealer is volatile until it dries. If wanting to get high or risk an explosion, do the procedure in a confined space. The high will also produce a pounding headache so I suggest performing the process outside.

The sealer takes about twenty-four hours to dry. Always be conscious of the gas tank's welds, particularly at the bottom. Make sure lots of sealer dries in these locations. Also, ensure that sealer has sealed all parts of the tank(s). Gently swoosh the sealer thoroughly all round the inside. I set the tank at different angles every hour, or so, to ensure a comprehensive job. Yes, you can go to bed as long as you did not start the process just before bedtime. The sealer must be tacky and not flow anymore.

Fuel Tank Storage: Filled and Empty

There are various trains of thought on this subject so the reader can pick which one best suits them.

1. The first methodology I am about to describe works well from an internal fuel tank protection perspective. The main recommendation in some manuals is to fill the fuel tanks using equal amounts of a mixture gasoline and oil. I find this labor intensive and potentially very messy. Furthermore, storage and disposal of the oily gas is necessary afterwards when putting fresh gasoline in. Running the oil-fuel mixture through the bike will produce noxious emissions but from a practical standpoint may foul the spark plugs, preventing spark arcing across the electrodes thus preventing engine operation.
2. I have always stored my bikes with a full tank of gasoline to prevent oxidation and condensation. Oxidation is a chemical reaction between oxygen (air) and another substance like bare metal, which will oxidize into rust. Condensation will also cause oxidation since oxygen is a key component of water as well as other chemical reactions. These oxidation reactions will compromise the integrity of the tank itself and pollute gas flow into the induction system. If the pollutants get through the carburetor or EFI components without disturbing their various internal functions (float-needle setting, plugging jets, orifices or injectors) they will most times burn in the combustion chamber. However, those that don't may score (scratch) cylinder walls and piston skirts, damaging piston rings in the process.
3. Gasoline may separate over time if it has an ethanol or other oxygenate component. Ethanol is hygroscopic, which means it can absorb water. It may be advisable to add a gasoline stabilizer to a full tank of gas for storage. It is certainly advisable to add to a partially filled gas tank since condensation will form. I have never done this but I always fill the tank right up so that condensation will be at a minimum. I have yet to have a bad experience but that does not mean it cannot happen. If the bike runs rough after bringing out of storage, the worst that happens is the gasoline needs to be changed. The rider can even get away with riding the bike, using up some fuel, topping up with fresh gas and continue this until the problem disappears.

Leaving a full tank of fuel for a few weeks or months will come with its own risks. This quantity of gasoline is very heavy so that pressure will be put on the gas petcock in use on carbureted Twin Cam models until the end of 2006. The petcock prevents the gas from gravity feeding into the carburetor and perhaps by the float and into the engine. It is essential that the carbureted petcock whether manually activated or vacuum-operated be in good working order to seal the gas in the tank. All late Evolution and Twin Cam carbureted fuel systems utilize a vacuum-operated petcock. Please see *Seasonal Fuel Valve Testing* further on in this chapter.

1. Many manuals advise draining the tank(s) and spraying (defogging or fogging) a rust inhibitor onto the insides of the tank(s). To me, this is just more work and expense. The bike may run rough for awhile after taking out of storage and refilling the gas tank. There are many commercially available inhibitors. If nervous, purchase from your local dealer or aftermarket shop. Follow the manufacturer's instructions.

The reader can make up his or her mind on the best methodology for them. Many riders like to do what their dealer recommends to avoid warranty hassles and the "I told you so" put-down lectures. However, some bike shops, dealers or otherwise will recommend a methodology that will allow them to sell you a product or service. Me, I check the integrity of the petcock and then I just fill the tank and leave it. Leaving EFI bike tanks full for storage is very safe also since gas must be pumped to the injectors. Worst case scenario at the end of the day is that I may have to run some fresh gas through my bike after initial start-up.

One last thing that should be done is to drain the carburetor float bowl. With the petcock in the OFF position, loosen the fuel bowl drain screw (bolt) a full turn to allow the float gasoline to drain away into a container. Retighten the float bowl drain screw. Do I do this? No, I don't. Occasionally, I have run across bikes where the gas has formed a white powder in the float but my experience is that it dissolves with fresh gas once the petcock is turned on. Again, the bike may run rough for a minute or two but should straighten itself out. If not flush the float and jets with gas. However, just because I can be a lazy...or is that prudent...person and avoid work that some feel necessary does not mean that you have to. I just do what works for me over time. When I find a reason to do work, I will be the first at it.

The very last thing is not to store the bike near open flames like pilot lights especially in enclosed spaces without air circulation. Use common sense.

Primer for Gas Cap(s) History

The longest serving fuel tanks are the duel cap/dual tank and later dual cap/single tank styling known as Fatbobs. I will use these for my example of improving sealing and fitment although many single H-D tanks with one fuel filler gas cap use the right-sided vented gas cap from the Fatbobs until later years when tanks like those used on 5-speed rubbermounts had their own design.

Harley-Davidson fuel tank(s) and gas cap(s) have undergone much redesign in the last four decades.

The old style 1936 to early-1973 vented gas cap (61103-36) and its rubber gasket (61111-77) along with the non-vented 1965 to early-1973 left side gas cap for dual fuel tanks (61103-65) and its rubber gasket (61116-65) had many serious problems especially as the mating tank and cap locking interaction wore with use.

1. It was possible via wear and vibration for a gas cap to fly off while riding, which of course, could lead to the rider getting soaked with fuel. If fumes ignited from hot engine parts or soaked ignition wires, it was all over but the crying.
    - The other main problem was aesthetic but also presented some danger as leaking fuel, especially from the left-side cap when the bike was at rest on its side stand would leave a puddle of potential danger as well as stain or remove paint from the gas tank surface.
    - Finally, gas fumes escaping through the cap and seal would destroy or stain paint around the fuel tank filler bungs.
2. The gas caps (61102-73 right vented, 61103-73A left non-vented) and fuel tank locking/filler bungs upgraded in 1973 for use until 1982. These were a big improvement but were still lacking.
3. In 1982/1983, the first excellent gas caps (61102-83A right vented, 61103-83 left non-vented) and gaskets (61109-83, 61109-83A, 61109-83B) along with upgraded fuel tanks were introduced. These were the first screw-in gas caps with a nice surface for the rubber gasketing to seal against. These caps have never flown off in my experience and are excellent at sealing both gasoline and fuel vapors inside the tank for the constantly also improving venting mechanisms to deal with.
4. The caps (61272-92A right vented, 61103-83B left non-vented) and gasketing upgraded again in 1992 with the best rubber gasket (61109-83C) thus far. It retrofits back to 1982/1983 and I highly recommend its use. The gasket is no longer thin and flat but resembles a skinny double donut that is much thicker and different shaped than its predecessors. It can compress and fill any warpage or unevenness thus preventing any gas or vapor from escaping.

Gas Tank Anti-staining

The H-D 61109-83C gas cap gasket was introduced to prevent:

- Evaporate from polluting the atmosphere.
- Fuel tank paint staining, discoloration, and/or the clear-seal from lifting off the painted surface.

Evaporate Gas

Gasoline evaporates naturally and easily into the air. A good fuel has this quality. It also makes it an environmental pollutant and thus a target of the EPA (Environmental Protection Agency) and CARB (California Air Resources Board) regulatory agencies.

Harley-Davidson's have had a vent hole in the gas cap forever. Older gas caps had a two-way venting system, which is just a hole whereby air could travel into the tank to fill space by the vacating gas. The gas cap vent also allowed evaporating fuel to vent out into the atmosphere. Only one situation exists at a time since evaporative build up will fill the void of draining gas and its pressure will even assist by pushing gas out of the tank that normally exits via the force of gravity. Therefore a buildup of evaporate gas will preclude the need for air to vent into the tank to fill the void of exiting fuel.

Modern Harley gas caps, which include those on all Twin Cams also vent but only one way. They allow air in as gas drains into the induction system whether it is carburetor or electronic fuel injection. Gas cannot feed out of the tank if a vacuum is created in the space it vacates. This is why air must vent in.

Later-style caps prevent vapors from venting out through the gas cap. These vapors feed back to a vapor valve in a singular basic way.

Some aftermarket gas tanks, like most Sporty and Softail replicas, have a standpipe. This metal tube runs inside the gas tank from the gas cap bung-tank down to an outlet at the bottom of the tank.

1. Some stock H-D tanks generally have the vent (standpipe outlet) underneath the dash panel. I have never liked this system because it is too close to the electrics like the wiring and the ignition switch. Electrical shorts and gasoline vapors can have very explosive relationships.
2. Other models will locate the standpipe in other safer places. Follow any small tubing around the gas tank and it will invariably lead to a gizmo called the vapor valve at one end of the tubing and the fuel tank standpipe at the other. An evaporative vapor standpipe may exit the tank at or near the bottom. Do not let this fool you as there will be an internal pipe going up above the gas line's highest point.

The gas cap screws into the gas cap bung. The portion that the standpipe connects to is always above the gasoline level inside the tank, no matter how much fuel is in the tank. A rubber line connects to the outlet at the bottom of the tank or under the dash or elsewhere as the case may be, and routes to a vapor valve (62150-85) on 1985 and later rubber mount FLT's, FLHT's, FXR's and 1991-to-present Evolution and Twin Cam Dynas. Resurrected Screamin' Eagle Twin Cam FXR's in 1999 and 2000 also use this methodology. Softails use the same vapor valve from 1985 to 1999 Twin Cams as well as into the 2000 to present Twin Cams.

The vapor valve usually locates:

1. Near the center frame down tube if on a Softail.

2. Rubbermount Dynas and FLT models do not have a frame down tube but the vapor valve will usually locate on the frame body that angle back and down to the rear of the gas tank.
3. On some models the vapor valve clips to the frame member immediately in front of the fuel tank.
4. Evaporative emissions controls (EVAP) on California models manage all gasoline evaporate from the tank and organizes carburetor throat and inside air cleaner fumes, when not running. The vapor valve that is found on the majority of models and years normally locates near the charcoal canister, which may be at the lower front of the bike by the frame down tubes underneath the charging system rectifier on Dynas; underneath the Softail rear frame axis, above the dual rear shocks; or between the battery box and frame members on later FLT models to give three examples.
5. Different years and models locate the vapor valve in convenient locations.

Follow the vent line away from the fuel tank to find the small black plastic vapor valve. The rubbermount models, particularly later year ones may have a fitting on the gas cap bung above the tank on the outside. A fuel door or a gas tank shield covers the raised gas cap bung with these tanks. A rubber hose will connect to this fitting. It then runs back and connects to the top of the vapor valve if fitted.

If the bike tips over too far beyond the lean riding angle, the vapor valve prevents gasoline from escaping through the vent. Two-safety reasons account for this.

The first is there will not be an expanding puddle of gas running out onto the ground and evaporating around a hot engine if the bike falls over.

- The second is to prevent evaporating venting fuel from escaping both for environmental and safety reasons. A hot engine, exhaust, electrical short, a lit cigarette, or other causes can easily ignite the vapor.

A hose connected to the bottom of the vapor valve directs the evaporation away. This hose leading away from the vapor valve routes downwards and vents into the atmosphere above the rear belt on FLT models. Other Harley's have the vent tube go to a fitting on a frame member. The evaporated emissions feed inside the frame tubing and escape out through open frame ends that are uncapped. Again, on California models as well as all 2010-to-present Harley-Davidsons, the evaporate fuel will not be free to go into the atmosphere but direct into the canister, which has differing designs over the years for purging and re-burning.

The goal is always the same: get the inflammable vapor away from the rider and any engine or exhaust component that has potential to ignite it. California takes this a step further for re-ingestion back into the engine for combustion up until the end of 2009. All 2010-to-present 50-State models come equipped with an exhaust catalyst.

Exhaust Catalyst

The 2010 exhaust systems also have an exhaust catalyst that locates for example in the new right side exhaust for the touring models. A catalyst exhaust system includes a catalyst housing having an inlet end, a passage, and an outlet end. The outlet end includes a valve seat.

An exhaust catalyst influences emissions depending on fuel composition. It is very important to follow H-D fuel recommendations for your year and model. This information is in the rider's manual as well as the workshop mechanics service manual. The amount of ethanol, methanol in the gasoline obviously affects its composition but also the heat generated (BTU's) and thus power produced. It also affects the Stoichiometric ratio or the air-to-fuel ratio where optimal burning occurs producing the most energy possible along with the fewest pollutants.

The modern adaptive learning engine management system that integrates spark timing with fuel delivery via information sent by various sensors like the oxygen sensors is also known as a closed loop system. This sophisticated and yet simple coordinated system controls the combustion functionality by monitoring various engine considerations including the exhaust oxygen sensor outputs. The oxygen sensors allow the creation of a closed loop EFI fuel delivery system that monitors and adapts to compensate for changes in fuel content and air density by adjusting the air-to-fuel ratio. Exhaust catalysts are a further refinement to achieving the most efficient air-to-fuel ratios.

Exhaust catalysts must remain functional for at least ten years or 100,000 miles (160,000 km). Exhaust catalyst health and efficiency depends on a minimum of outside interferences like excess sulfur in the gasoline. As always, the push is on for a cleaner fuel. However oxygen intrusion must also be kept at a minimum. By this, I mean air leaks into the exhaust pipes through gasket and joint seals. From 2010 to present, Twin Cams and Sportsters have exhaust pipe functional or slight upgrades some of which are:

1. The exhaust pipe endform that meets the exhaust port on each head is now spherical in shape to improve fitment and sealing capability.
2. Exhaust pipe consistency at the other end where meeting the muffler also improves. There is a developed rib and curl end presenting a positive muffler stop for joining the muffler to exhaust pipe.
3. The Dyna crossover exhaust joint improves sealing via a new gasket and clamp. Clamp torque specification is 15 ft-lbs to 19 ft-lbs (20.3NM to 25.8Nm).
4. The new 2010 Fat Boy Lo known as the Fat Boy Special in HDI and HDE countries has exhaust shields coated in Ceramic, which is a high temperature ceramic coating. This may be more than a cosmetic change as ceramics hold heat in.
5. Softail models also have the new efficient endforms at the heads and at the muffler joints along with the new muffler clamp and gasket.
6. Softail mufflers have new internals with improved sealing at the exhaust catalyst with a new pipe to muffler seal.
7. The Softail Rocker crossover exhaust tube has the previous mounting wedges removed. There is a new interconnect gasket and clamps at interconnect joints.

California (CARB) Vapor Re-burning

CARB is the acronym for California Air Resources Board. It is a stricter California state only version of the federally mandated EPA (Environmental Protection Agency). CARB is necessitated by two overriding factors.

1. Heavy population concentrations particularly in the greater Los Angeles area. The car culture produces harmful emissions that have nowhere to go. This is the difference between the West Coast and the east that also has heavy population concentrations. East Coast emissions can dissipate somewhat via prevailing winds.
2. The mountain ranges that run north and south trap the emissions over the Western populated areas so that smog concentrates.

Therefore, California generally leads the way in dealing with harmful emissions. Emissions controls introduced in this leading edge, environmentally progressive state will generally spread to the rest of the country and Canada later. I will give a brief history of these emissions controls and how they have evolved until present day.

EVAP California Emissions Controls: 1985 to 1987

Before Reed Valve technology introduced in 1988 to deal with fuel vapor inside the air cleaner after the bike stops running, H-D necessarily began following CARB dictates to redirect fuel tank fumes via the evaporative hose, through the vapor valve and into a charcoal canister for purging. This is known as EVAP (Evaporative Emissions Controls System), which controls hydrocarbon vapors escaping into the atmosphere. Three hoses enter or leave the canister:

1. The evaporative hose carries fuel vapor from the gas tank via the vapor valve into the canister.
2. The clean air hose connects the carburetor air cleaner to the canister to supply clean air.
3. The purge hose from the canister to the air cleaner allows vapors to flow up into the air cleaner for ingestion into the combustion chamber on startup. The descending pistons on the intake stroke provide this impetus by creating a negative pressure inside the air cleaner.

California CARB Reed Valve: 1988 to 1991

This updated system adds another feature to the earlier one. Vapor hanging around inside the sealed air cleaner can move down into the charcoal canister or remain sealed inside the air box until startup when the vapors will suck into the combustion chamber. California Harley reed valve methodology is the forerunner of the 1992 to 2006 solenoid-operated butterfly valve in the air cleaner that connects to the carbon canister. Reed valves are most commonly used internally in 2-stroke engines. A reed valve is basically a one-way valve sometimes descriptively called a flapper valve that operates on negative (vacuum) and positive air pressures. There are two reed valves that locate equidistant, bottom left and bottom right on the rear of the carburetor air filter housing backing plate. They are not noticeable because the backing plate faces the engine. Each assembly consists of a bottom reed and top reed with a reed stop. The reeds close, sealing the carburetor air box (cleaner) when the engine turns off. When the engine is running, negative air box pressure opens the reed valves and allows purged gas vapor to return from the carbon canister into the air cleaner for re-ingestion into the combustion chamber.

Damaged or broken reed valve components may reduce top speed and result in poor acceleration. The reason is the reed valve may stay closed or partially closed when the engine is running thus starving an air source.

Furthermore, if a damaged reed valve stays open when the engine stops, evaporates will escape into the atmosphere causing a source of pollution.

VOVS: Vacuum Float Bowl Vent Cutoff

The VOVS is the acronym for a repetitive but descriptive phrase: Vacuum-Operated Vacuum Switch. When the engine is not running, the VOVS closes off the carburetor float bowl vent passage. This will curb another pollutant source of gasoline evaporate. The VOVS also disrupts the vent's function as an overflow hole if the float is maladjusted or malfunctions when the engine is not running. VOVS part number for all 1988-1989 Big Twin models is H-D 27028-88 and for 1990 and most 1991 models is H-D 27028-90

- A rubber tube connects the vent overflow tube to the small VOVS switch locating behind the carburetor under the manifold.

- Another short line continues from the VOVS switch up to a fitting that feeds into the top of the rear of the carburetor or the manifold depending on year and model.
- Intersecting the VOVS and the carburetor-manifold fitting is the VOES switch (Vacuum-Operated Electrical Switch).
- I know, this is all beginning to sound very complicated but it isn't. The VOVS switch is mechanical:

1. Vacuum causes it to operate.
2. Atmospheric (positive) air pressure ceases VOVS operation.
3. So, where does the vacuum originate that operates this mechanical switch? It comes from the rear of the carburetor body's throat or the manifold. The same vacuum caused by air rushing by through the manifold into the cylinders and combustion chambers that operates the VOES switch also does double duty and operates the VOVS emissions control switch.

The VOES switch has an electrical component in addition to its mechanical one. It feeds vacuum information via electrical pulses to the engine management system's electronic control module. The ECM then instructs the spark plugs when to fire via electrical pulse. Manifold vacuum indicates whether the engine is under load (acceleration or cold idle) or not. If accelerating, piston speed increases, thus the spark plug must go off sooner (advanced ignition timing) to allow complete or near-complete combustion to occur at the correct time. Combustion takes a certain amount of time. Combustion heat expands driving the piston down to create power. Combustion must near completion as the piston begins descending on the power stroke.

Therefore, monitoring vacuum or negative pressure, not only aids in emissions controls but performs its primary function of timing spark ignition also known as ignition timing.

California CARB Vapor Re-burning: 1992 to 2006

1. On Harley-Davidson's produced for California, the secondary vent tube from the vapor valve is fed into a charcoal canister bottom fitting, marked TANK where the fumes are stored when the bike is not running.
2. The fuel vapor vent tube originates with a fitting on the filler gas cap bung or another location above the full level of the gas tank(s). The vapor vent tube funnels gas vapor down to and connecting with the top of the vapor valve.
3. The vapor valve will also prevent the loss of gasoline through the vapor tube if the bike falls over.
4. When running, the vacuum…negative pressure…created in the carburetor venturi via sucking pressure produced by the descending pistons on their intake stroke will draw the gasoline vapors from the charcoal canister up the purge hose back to the carburetor where they are ingested and burned in the combustion chamber. The purge tube connects to the charcoal canister top left-side fitting, marked CARB and then connects to a fitting on the carburetor or the induction module as the case may be.

5. The charcoal canister on California bikes must deal with another source of gasoline vapor. Gas fumes also hang around the carburetor throat. These vapors originating inside the carburetor throat draw through a hose connected to a fitting in the inboard or backside of the air breather backing plate called the clean air inlet. This hose also feeds down to the right side of the charcoal canister-holding container drawing fresh air down the clean air outlet to assist in purging the vapors in the canister back up to be re-burned. An electrical solenoid opens a butterfly seal on the backing plate on 1992 and later models when the ignition turns on to open the clean air inlet. When the ignition is off, the solenoid butterfly plate closes the opening to the clean air inlet in order to attempt to seal any hydrocarbon vapors in the air cleaner.
6. The clean air inlet tube is not used on fuel injected models because vapor hang-around in the throat of the air cleaner is not an issue with injectors pointed towards the valves deep inside the induction module. On EFI models, the free end of the 90^0 clean-air-tube-inlet-fitting on the right side of the charcoal canister is pointed downwards.

A faulty solenoid-operated butterfly valve or the gravity operated baffle plate at the air cleaner inlet port will definitely reduce top speed and result in poor acceleration. Again, it will allow the valve to close when the engine is running thus starving an air source.

If for whatever reason, the rider or customizer wants to relocate the carbon canister it must be below the carburetor to function.

Finally, pay close attention to the routing of the 4-wire loom connecting to the solenoid to bike's wiring harness. One of these wires connects to the starter relay and then to the ignition circuit breaker. If these wires vibrationally rub against mating parts or gets pinched all types of problems may occur. One example could be intermittent ignition operation. This would be tough to resolve. Why would a mechanic look at the evaporative solenoid butterfly seal to determine an ignition problem previous to this discussion?

California CARB Vapor Re-burning: 2007-to-present

On 49-State models where there is no charcoal canister, the vapor valve tube vents to the atmosphere.

The charcoal canister attachments are essentially the same as in earlier EFI models. All 2007-to-present Harley-Davidsons are fuel injected. Therefore, the free end of the 90^0 clean-air-tube-inlet-fitting on the right side of the charcoal canister is pointed downwards. The clean air tube connects to the carburetor backing plate as is necessary with carbureted models that generate gas vapor inside the air cleaner. This is not required with EFI models as the induction process is much more efficient and does not generate the same wayward vapors as do carburetors.

The Vapor Valve

In addition, *crankcase-venting* vapors feed into the air breather for re-ingestion into the engine. Those vapors that are not sucked in via venturi vacuum when the engine is stopped can also feed into the clean air outlet in the carburetor backing plate and down the connecting clean air inlet hose and flow into the charcoal carbon canister reservoir.

These purged fumes will then flow up the purge hose from the carbon canister when the engine starts.

- The vacuum created by the descending pistons on their intake stroke will create the negative pressure to draw up the purging fumes.
- Thus, both crankcase and carburetor throat fuel vapors that feed into the carbon canister draw up the purge hose into the carburetor and into the combustion chamber where they burn.
- EFI model fuel injection systems do not have the same level of vapor wandering, as do the carburetors that rely on the physical laws of nature to operate. Delphi EFI injectors spray gas under pressure in controlled bursts towards the valves and into the combustion chambers. Excess gas is pumped back into the gas tank. In my opinion, a defect in the Evolution and Twin Cam Magneti Marelli fuel injection does not do this exactly as the injectors point in the wrong direction, but the much-improved Delphi system introduced circa 2001 corrected and enhanced fuel delivery. Air flowing through the intake runner of the EFI system ably assists in taking errant vapors into the cylinders for burning.

Whether the fuel tank vapors vent to outside atmosphere to the rear of the engine or into a charcoal canister to purge and burn in the combustion chamber, they must go through the vapor valve. I describe earlier, some locations for the vapor valve on different models. Following the fuel tank evaporative (vapor) hose will always locate this small black plastic valve. The vapor valve is another one-way regulating control device with an internal ball and seat arrangement; at least that is what it sounds like when shaken.

The 2 ½"-long durable black plastic vapor valve is a sealed unit that looks similar to a gas filter except there is no viewing window.

- The upper ½"-long, $^{3}/_{16}$"-diameter nipple feed inlet is designed for a ¼"-flexible hose.
- A wider diameter ¼"-wide protrusion extends down one-half inch and houses a needle/ball and seat apparatus.
- Next, the body that houses the valve weight arrangement is ¾" in diameter and at its widest point is about ⅞"-long.
- From this extends an identical ½"-long lower $^{3}/_{16}$" diameter nipple for a ¼"-hose fitment.

One nipple end connects to a flexible hose that extends up to the fuel tank standpipe. The other nipple connects to a hose that directs evaporate away from the hot engine and exhaust to dissipate into the atmosphere on 49-State motorcycles and into the charcoal canister on California CARB bikes.

I thought I would find a simple ball bearing that would rest in a seat much like the system in pre-1999 oil pumps that is supposed to prevent gravity feed of oil into the bottom end when the bike is at rest. I could not contain myself so I cut one open to find a much more sophisticated spring weight activated seat and needle system than I expected.

A light spring sits underneath the weight.

- The weight sits under a guide.
- The guide sits inside the needle on top.
- The needle is similar to one found in a carburetor float bowl. The needle can mate in its respective seat that is part of the plastic housing *when the vapor valve turns on its side or is upside down.*

The longer portion of the vapor valve *must* face *vertically upwards* to function correctly as designed.

- When on its side the spring can close the needle valve on its seat.
- If upside down, the weight will take over and firmly close the needle into its seat.
- In these last two situations neither gasoline nor evaporate can exit (escape) the vapor valve. This obvious safety measure will prevent a potential fire hazard during an accident or when the bike tips over for whatever reason. It also limits minor environmental pollution.

Continuous Venting: 1992 to Present

Physics 101 dictates that gas tanks need to vent air in to replace evacuating fuel or the ensuing vacuum will prevent fuel flow to the carburetor. Expanding gas fumes also need to vent out of the tank or gas may force by a weakened carburetor float mechanism. The float controls the flow of gas in the carburetor while ensuring there is a steady supply on hand. The 40mm CV Kehein carburetor necessitated the development of *continuous venting* of the gas tank(s) to ensure:

1. Constant fuel supply.
2. The prevention of carburetor overflow.
3. The curbing of fuel spray back.
4. Improved gas mileage.

Continuous venting carries on with all EFI models. Is this development too simple to mention? Try riding a bike with venting issues. The experience will be aggravating to say the least.

At first glance, one would think that these internal vapor valve parts are in upside down since gravity prevents the needle from mating with the seat on top of it. It is exactly as designed. The fuel vapors and vented crank oil vapors need to flow past the needle and seat arrangement at will when the bike is upright to dissipate into the air behind the engine and away from the hot exhaust pipes or safely into the California emissions charcoal canister.

If the bike falls over the weight, assisted by its spring, will gravity press against the needle guide pushing the needle into its seat. The vapor valve will now block liquid gasoline that may flow out of the gas tank from continuing any farther through the vent vapor tube. If installed upside down by an errant mechanic or its hold-down bracket fails to secure it in its proper upward position, the valve and seat will prevent vapor from going through the valve. This can result in an excessive buildup of vapor in the gas tank. If the vapor cannot find another way to escape and equalize pressure then excessive pressure buildup in the gas tank can force fuel down into the carburetor. EFI models will resist this pressure and will look for the next path of least resistance, which will likely be a fuel tank seal.

The Float

Normally the carburetor float mechanism will stop excessive flow and act as a dam against more fuel coming into the carburetor venturi or out the vent. A float is an airtight hollowed out donut-shaped apparatus made from very light and thin metal-like brass. Some aftermarket ones are solid, made from a non-porous light material that floats in a liquid. The float regulates the float bowl and its fill amount. The attached needle regulates the float gasoline up to its pre-set level. The Factory or a mechanic adjusting the float level usually does so by bending the thin metal tab protruding from the float that attaches to the needle. This mechanism keeps a reservoir of gas at the ready to draw up into the carburetor venturi via negative pressure (vacuum), created by air moving through the venturi. As gas draws up, the float lowers, lifting the needle out of its seat allowing more gas to enter via the force of gravity to fill the reservoir. Once the float reaches the adjusted level it prevents more gas from entering by forcing the needle down into its seat in the fuel inlet fitting.

Diagnostic Skills: Gas Overflow

I will state the obvious that gas overflow is dangerous especially on a hot bike. With diagnosis of any problem, I always examine inexpensive and easy fixes first and progressively expand to more costly and difficult solutions. This practice will save much money and effort. For example, if a customer complains of an engine knock, I will not tear down the engine as the first option. Many shops will.

Do the free things first taking advantage of your senses. Actually, this is very wrong. First, think of safety precautions when working with flammable fluids.

Safety

1. Grab the fire extinguisher and have at the ready.
2. Move the bike into the open air if in a confined space like a garage or around other expensive motorcycles and machinery.
3. Ensure there are no sources of ignition.
4. If the bike is running, turn it off.
5. If anyone is smoking ask him or her to leave the immediate area.

Isolate the Problem

If the bike has a manual or vacuum operated petcock turn it to the OFF position to starve the problem in case the gas leak is downstream of the fuel tank.

Use the Four Senses for Free

1. Visually observe the problem area. If gas is overflowing on the bike look at the fuel tank, fuel tank fittings and lines, the induction system (carburetor or EFI), as well as connecting or linking parts such as vent lines and the vapor valve.
2. A sense of smell will indeed confirm overflowing gasoline, an overworked clutch or a rubbing tire to name a few examples.
3. Touching will confirm whether gasoline overflow may originate in an area that the mechanic cannot readily see like from a split weld underneath the gas tank.
4. Turn the radio off and listen. You can hear gas dripping on a hot exhaust pipe and perhaps smell it. You can also hear escaping venting gas evaporate.

Thus, the initial diagnosis does not involve any tools whatsoever especially expensive specialty diagnostic ones. Therefore I smell, look and feel for problems. Where I smell, look and feel will depend on the customer complaint.

Vacuum Operated Gas Valve (Petcock)

Electronic fuel injection uses a pump to deliver fuel to the fuel injectors that respond to the dictates of the electronic control module. Therefore, only carburetion utilizes a fuel (gas) valve better known as a petcock in my neck of the woods.

Installing a Petcock (Fuel Valve)

Special concern for safety precautions must be taken with motorcycles because most vehicles prudently place the fuel tank out of harm's way and not sitting over a hot engine and header exhausts. Therefore, it is also sensible to take care with a fuel petcock that also locates over a hot engine. A gas leak, weeping gas and/or vapor seepage has much potential for a dangerous situation.

All Twin Cam petcocks are of the new vacuum-operated style that has a pressure jam nut that fits over and threads onto a male bung on the left side of the fuel tank. There are three sealing components:

1. There is a rubberized gasket (62172-75, 62172-02) that fits on the fuel valve (petcock) body underneath the nut portion attaching to the body.
2. The fuel strainer is plastic. It fits up into the fuel tank. It is held firmly in place against the bottom of the fuel tank/petcock attachment bung via a wider diameter base. The fuel petcock body presses against the plastic base when the nut is fully threaded onto the petcock bung.
3. Finally, the mechanic should either use a Loctite pipe sealant with Teflon or a sealing adhesive like Hylomar PL32/L25. Coat the threads and tighten the petcock screw-on jam nut to its gas tank bung fitting to 18 ft-lbs (24 Nm).

Carbureted Gas Petcock Blockages

The petcock, a shut-off valve, is usually located at the bottom rear of the left tank or the left side of a single tank, is not at the absolute lowest point but close to it in order to allow heavier sediment in the fuel to settle below. Where does this sediment come from? Oxidation (rust), of the motorcycle tank insides, over spray when the tanks are painted, dissolved paint chips from the gas cap bung and of course, impurities in the gasoline itself all contribute to this problem.

Always patronize a busy gas station. Ones that do not pump much fuel will have higher water condensation buildups in the fuel, more sedimentation from oxidation inside the stations holding tanks and separated chemicals in the gas. For example, alcohols (ethanol and methanol) just love to separate from the gasoline over time. Ethanol is hygroscopic, which means it will absorb water condensate or even moisture in the air in the fuel tank.

This simple petcock location methodology seeks to prevent sediment interfering with gas flow through the fine filter (62170-81A, 62170-02) inside the tank attached to the petcock. The filter captures floating particles and prevents them from interfering with the float mechanism in the carburetor.

The float is a hollow donut-shaped part that floats on top of the gas in the float bowl normally located at the bottom of the carburetor. The attached float needle that sits in the entrance way is adjusted to allow gas to flow into the float bowl until the float donut tops out and prevents more gas from coming in. This allows a reservoir of fuel to be available at all times.

Sediment can lodge between the float needle and its seat, causing an overflow of gas into the carburetor when not needed. This overflow may foul the spark plugs but will also find its way out of an overflow hole, usually on the side of the carburetor above the normal position of the float. The overflow may also be a standpipe in the float bowl from bottom-to-top. It affixes at the bottom with both ends open. The top end is above where the float sets. If the float overwhelms or is misadjusted, fuel will run into the standpipe and flow down out of the bottom of the carburetor float bowl housing. Gas will flow out this hole and down onto the engine on older Harley's. H-D wisely put a fitting into this overflow hole and attached a hose onto the fitting. The hose must direct away from hot engine parts and the exhaust so that the overflow harmlessly deposits onto the ground, not that gas is harmless. I am sure this simple hose attachment has stopped many an injury or deaths and protected the manufacturer from an ever-increasingly litigious public.

Manual Fuel Valve (Petcock)

Turning the carbureted fuel supply valve or petcock (62167-81, 61335-83, and 61338-82) handle:

1. Horizontally is the OFF-position.
2. Vertically down is the full-ON position.
3. There is a RESERVE position when the main fuel supply is low, which is vertically upwards.

I cannot repeat enough that the fuel supply petcock should always be turned off when the engine is not running. The danger of gasoline leaking into the cylinders can lead to catastrophic engine damage. The manual petcock phased out beginning in 1994 when the vacuum operated petcock began to see first use on carbureted models. EFI does not use a gas petcock.

I check manual petcocks as well as vacuum-operated ones once a year to ensure the valve mechanism is not leaking, thereby protecting the engine's lubricated cylinder walls from gas wash-down.

Seasonal Fuel Valve Testing

I must say that the single most problematic part on a Harley-Davidson, probably generating more money in my repair shop than any other is both types of petcocks. No matter how much I lecture errant riders into always turning their petcock off when shutting down their bike; many still leave it on. This allows the full weight of the tank gasoline to push down into the carburetor float bowl that is no longer moving fuel. The relatively weak float must contend with all the weight sometimes allowing gas to leak by. When the bike is running, this is not a danger unless the float becomes defective since gas uses up constantly and the float bowl must replenish steadily.

When gasoline leaks by, it will make its way into the engine washing down the cylinders. This very effective cleaning process robs the cylinder liners and the pistons necessary lubrication on startup. Furthermore, the gas mixes with engine oil to form an abrasive. This simple action of leaking gas mixing with the lubricant oil destroys engines.

It is a good idea to fill the gas tank for storage over the winter to prevent oxidation and ethanol hygroscopic moisture absorption. It is just as important to check the petcock, whether manual (62167-81, 61335-83, 61338-82) or automatic vacuum operated (61338-94, 61338-94A, 61338-02 FLT) to ensure it does not allow leakage *when in the OFF position*. Repair shops lost much income with the advent of the automatic shutoff petcock that is until the internal diaphragm began to wear. When getting your bike ready for winter storage or any other long period of inactivity:

Turn the petcock off.

1. Then disconnect the fuel line from the carburetor and run it into a glass bottle or approved plastic gas container. Unapproved containers may partially dissolve into any gasoline draining into it. The bottle should be able to potentially hold the amount of gasoline left in the tank.
2. Leave for overnight.
3. Inspect, the next day. There should not be any gasoline in the bottle. If there is, the petcock's sealing ability is impaired.
4. If there is leakage, replace the petcock.
5. Retest the new petcock overnight.

This will help ensure that there will be no gas wash down.

When first starting the bike after storage if there is the smell of gasoline or oil/gas pukes out of the engine case breather or the air cleaner breather, shut the bike off and inspect the oil via touch, rubbing some oil between your fingers, and smell. If gas is mixed in, change the oil immediately. Squirt some oil into the cylinders through the spark plug holes and manually turn the engine over a few times to provide piston and piston ring lubrication. Run the engine for a few minutes and change the oil again. If too lazy to follow this procedure, I will be available to do a rebuild for you. The engine may not need one right away but that day is now much closer than it was.

Vacuum Operated Gas Petcock

Like the manual fuel supply valve petcock, the vacuum operated petcock's OFF location is with the handle in the horizontal position. Turning the handle down to the vertical position is the full-ON position. There is a RESERVE position when the main fuel supply is low, which is vertical but upwards. The petcock is vacuum operated and opens and closes when the engine is running or is turned off. Again, the petcock should always be turned off when the engine is not running to prevent gas from draining into the engine. Many riders depend on the lack of vacuum to turn off the petcock. Of course, how many riders even know or thinks about this good-habit mechanical exercise.

In order to flow gasoline into the carburetor, the vacuum operated petcock:

- Handle must be vertical down (fuel supply ON) or vertical up (fuel supply RESERVE) before gas will flow.
- A vacuum of 0.5" to 1.0" Hg (Mercury) must apply to the vacuum nipple that locates at the rear of the petcock.

What Turns on the Vacuum Operated Petcock?

Manifold vacuum operates this petcock. A rubber hose connects the vacuum nipple on the vacuum operated gas petcock to the manifold. The nipple locates at the rear of the petcock, pointing upwards. When the engine is running, the vacuum created inside the intake manifold will in turn operate the vacuum operated petcock. There is a diaphragm between the rear vacuum nipple and the gas flow tube from the fuel tank. When a partial vacuum condition exists in the carburetor manifold because of air traveling through when the engine is running, a partial vacuum will also transfer through the connecting tube to the vacuum nipple and one side of the diaphragm. The other side of the diaphragm vents to the atmosphere via a bottom fitting on the fuel valve called the atmospheric pressure port. Thus, the opposite side of the diaphragm is always at atmospheric pressure. The vacuum nipple side of the diaphragm activates when a partial vacuum exists and moves it over via the pressure differential against a spring. This opens the fuel supply. When turning the engine off, the partial vacuum returns to atmospheric pressure thus cutting off the supply of fuel to the carburetor as the diaphragm shifts to the closed position.

Utilizing Manifold Vacuum

Manifold vacuum is used for:

1. Operating the VOES or vacuum operated electrical switch that sends electrical pulses to the ECM to indicate whether the engine is under load or not.
2. Operate the VOVS or vacuum-operated vacuum switch found on earlier Evolution models. The VOVS closes off the carburetor float bowl vent passage when the engine is not running.
3. Operates the vacuum-operated petcock from circa 1994 to 2006 on all carbureted Big Twins. There are no petcocks after 2006 since all 2007 and later models are electronically fuel injected.

Is the Vacuum Operated Gas Petcock an Improvement?

At first blanch, it certainly seems to be a huge improvement over the manual petcock. And it is…if the Harley rider uses the manual component and turns the gas on and off religiously. In this scenario, there are two fronts against cylinder wash down:

1. The manual component where the rider turns the gas off whenever stopping the bike.
2. The vacuum-operated automatic shut-off feature.

Unfortunately, in my experience very few riders pay any attention to the manual shutoff. In addition, I do not believe that many dealers educate riders as to the dual shutoff feature. Furthermore, I must confess that I did not think much about the vacuum-operated petcock working in tandem with the manual component either until I started writing this book. I am a now a convert and am preaching again.

Vacuum Petcock Problems

In 2004, I bought a brand new carbureted TC88 Softail Standard. I wanted a reliable chopper. I took off offensive parts to the genre I was building like the turn signals. I then radically raked the frame, extended the Wide Glide front end and on it went. I did not touch the engine, carburetor or gas tanks. I did not need faster because of the drastic handling changes.

Shortly after beginning to ride it, I began complaining to Stevie, my head wrench that the bike lost power going up steep hills and in top end riding situations. We looked at all the usual suspects to no avail; spark plugs, fuel tank and gas cap venting, electrical and carburetor jetting to the point this was becoming a frustrating problem. Finally, out of desperation we checked the vacuum of the fuel valve. After all, this was a brand new bike so I made the misassumption the fuel valve was good. On older bikes I do not make this assumption. In fact, if the bike were not new, we would have found the problem much faster. Well, I think that is enough rationalizing. Steve was able to draw air through the petcock indicating there was not a full seal. Therefore, negative pressure (vacuum) could not fully activate the diaphragm. As a consequence it only opened partially. The bike ran fine with low fuel demand as in normal riding but as soon as encountering high top end speeds or long steep hills, the petcock was unable to supply the full complement of fuel necessary.

We now move checking vacuum-operated petcocks up the list of checks right after venting when encountering this type of problem. I may learn lessons hard but once learned I am like a dog with a bone.

In fact, we now have a policy of checking every vacuum-operated petcock on every bike that comes in since it takes little time and may save much aggravation and potential engine damage. It is amazing how many defective petcocks or partially defective and wearing vacuum-operated petcocks are out there. Some think we are the miracle workers because we do this simple check as well as others but it is just prudent maintenance that exposes impending problems in advance.

Furthermore, many tune-ups really have to do with the vacuum elements of the VOES switch, the Evolution VOVS and the vacuum-operated fuel valves. For example, the petcock diaphragm normally rots around the backside allowing air to travel through it creating positive or neutral pressure thus preventing the fuel valve from operating properly via negative pressure.

Take Nothing for Granted

An interesting problem with vacuum-operated petcocks occurred in 2005 with carbureted Twin Cams that were built in October and November 2004. The petcocks on bikes built between the dates listed below in the table were mis-manufactured by the vendor (supplier). The ON and RESERVE positions on the petcock were reversed. Therefore when a rider turned the petcock to the ON position, it was really in the RESERVE spot.

Consequently, when the rider put the petcock in the RESERVE position after the fuel ran out from the ON position, there would be no fuel whatsoever causing the bike to stop running. How many times does your bike run out of gas in front of a gas station? Furthermore, the bike may stop at a bad time creating a dangerous situation, an example of which would be passing a tractor-trailer with another headed towards you. The petcocks are non-serviceable and must be replaced.

The problem affected 49-State and California bikes, as well as HDI international export models. The list of affected motorcycles was shipped between October 11, 2004 and November 19, 2004. Consult the chart below.

Check with your dealer giving the VIN (Vehicle Identification Number) of your motorcycle to confirm if the service has been performed. Quote M-1167 Safety Recall Code 0118 dated January 26, 2005. The dealer should have a "B" VIN list. If the bike VIN is on this list, replace the petcock, as it is certain that it is a faulty one and the following inspection procedure is not required for a determination of defect.

There is an interesting, to me anyway, procedure to determine if the bike has an installed mis-manufactured petcock. This test will not likely be necessary since you, as the rider will know from riding the bike if the petcock positions are reversed.

1. Perform the test with the bike resting on its sidestand in an open area.
2. Drain the bike of fuel and refill with only ½ U.S. gallon (1.9 liters) of gas.
3. Turn the petcock to the ON position.
4. Turn ignition on and try to start the bike.
5. If the bike will not start, turn the petcock to the RESERVE position:
    a) Attempt a restart.
    b) If the bike starts, turn the petcock to the On position again while running.
    c) The bike should stall within three minutes and probably closer to just under two minutes. The fuel petcock does not need replacement.

6. If the bike starts when the petcock is in the On position:
   a) Turn the petcock to the Reserve position while running.
   b) If the bike stalls after the time it takes the float bowl to empty then the petcock is a recall one that needs replacement.

It is still possible that there may be packaged for sale defective petcocks floating around although Harley-Davidson issued the information to dealers for a return and replace procedure. It amazes me how this stuff can find its way onto the Internet for sale to unsuspecting buyers. I know one thing for sure and that is H-D did everything it could to remove the mis-manufactured petcocks from the supply chain. However, there will usually be an unscrupulous person somewhere in the supply chain that will take advantage of making some free unethical money. Interestingly, there are some Evolution petcock part numbers on this list.

Affected H-D Motorcycle Mis-manufactured Petcocks

Model Group	Ship between dates	
Softail FXST-FLST	Oct. 18, 2004	Nov. 19, 2004
Touring FLH series	Oct. 18, 2004	Nov. 19, 2004
Dyna Glide FXD series	Oct. 12, 2004	Nov. 18, 2004
Sportster XL series	Oct. 13, 2004	Nov. 18, 2004

Parts Department Defect Petcock Ship Dates

Model Group	Petcock	Ship between dates	
Softail FXST-FLST	61338-02	Oct. 11, 2004	Nov. 02, 2004
Softail FXST-FLST	61338-94D	Nov. 09, 2004	
Touring FLH series	61338-02	Oct. 11, 2004	Nov. 02, 2004
Dyna Glide FXD series	61338-02	Oct. 11, 2004	Nov. 02, 2004
Sportster XL series	62169-95C	Oct. 19, 2004	Nov. 17, 2004
Sportster XL series	62169-02A	Oct. 26, 2004	Nov. 16, 2004

If purchasing a petcock for your Twin Cam or Evolution check the part number and shipping date correlation to determine if it is mis-manufactured. This information will be on the sealed H-D bag and/or shipping box. It is unlikely that an H-D dealer will have any of these in inventory but it is certainly possible that some are floating around for sale on the Internet or at swap meets.

Petcock Upgrades and Changes

The reader can easily discern that the various vacuum-operated petcocks went through a series of updates over the years since their introduction in 1994 to 1995:

1. The suffix of a part number gives first year of use. A letter after the suffix denotes an improvement or upgrade. For example part number 61338-94D from the above chart indicates first use is in 1994 (94) and that this petcock is a 5th generation one. There will be four part numbers over the years: 61338-94, 61338-94A, 61338-94B, 61338-94C, and 61338-94D.

2. Secondly, since we know that first use of the vacuum-operated petcock began in 1994 to 1995 that any part number suffix after these dates would be a whole new petcock. I hypothesize that the Factory introduces a new number for the same basic but improved part because the succession of suffix letters might give one pause to think what was wrong with that part anyway to have so many changes? I might be wrong, who knows? Therefore, we have a part number, again taken from the above chart with the same prefix but a 2002 suffix, 61338-02.
3. Of course, if we look at the Sportster part numbers, they will have a different prefix than Big Twin models because of space considerations or outlet direction. Therefore, the Sportster part numbers, namely 62169-95C and 62169-02A, indicate a succession of improvements to both base part numbers for a vacuum-operated petcock: 62169-95, 62169-95A, 62169-95B, 62169-95C as well as 62169-02 and 62169-02A. This indicates six improved petcocks over eight years.

Fuel Tank Venting

It is easier to understand Harley-Davidson progression and advancement if viewing components from an historical perspective.

1984-1991: The Simple Gas Cap is not Simple

The gas tank(s) depending on model whether there are two halves to make one complete gas tank set as with the early Softail models or one gas tank on FXR, FXD, and FLT models vent through the gas cap(s). The 1984 to 1991 gas caps are not designed for 1992 and later models. They vent via a pressure/vacuum relief valve in the single gas cap or the right gas cap if a dual gas cap set-up. With built-in limitations, air can flow both ways through the early-vented gas cap. The vacuum caused by gas flowing out of the tank will pull open the vent to allow air to flow in and replace the volume of liquid leaving. As evaporate gas builds up, it will push the valve the other way to open so pressurizing evaporate can flow out. As pressure equalizes, inside and out with both scenarios, the valve will close. The simple gas cap is not so simple.

How does the valve open and close? Certainly negative pressure will open it to allow air in and positive pressure greater than atmospheric pressure will open it the opposite way to let expanding evaporate out. How does the valve close from either direction as pressure equalizes? Two springs are the answer, one on either side of the shutoff/open plate. A heavier and larger diameter spring is on the outside and a smaller diameter and weaker spring fits inside. They do not work against each other so much as engineers want more evaporate expanding pressure to compress the heavier spring to open the valve and less spring pressure to open the valve the opposite way in order to let air in. One reason for a heavier spring is a safety one. If the bike falls over, it will take more pressure to open the valve to let dangerous combustible gas to flow out of the vent. Each spring is strong enough to activate the closing of its valve once atmospheric pressure equalizes on both sides. Either spring does not push open their respective valve but provides seating resistance as both expanding gas and negative vacuum pressure causes their respective valve's to push open. The spring only pushes the valve back against its seat as gas tank inside and outside pressures equalize.

The valves for each spring are ingenious in design. The opposite ends of the springs fit into metal carriers for base support. The flat dual valves fit against and with each other. The smaller flat plastic valve has an appendage that fits through a hole in the center of the larger diameter flat rubber valve so they constantly align together. As expanding evaporate internal tank pressure forces open its larger rubber valve for venting, the smaller plastic vacuum air valve seats against the center hole as if both pieces were one.

As negative pressure (vacuum) builds with draining gas inside the tank, the pressure differential with the outside atmospheric pressure opens the smaller plastic valve until air can rush through the center hole in the larger rubber valve center. As pressure equalizes, the smaller spring pushes the smaller plastic valve against the larger rubber valve face thus closing off the travel of air. The weight of atmospheric air and evaporate gas pressure differentials are greater than the strength of their respective springs. This is what makes the valve system work, simple but irrefutable physics. There is a disassembled dual-venting gas cap picture in Volume III: *The Evolution: 1984 to 2000.*

1992-to-Present Evolution and Twin Cam Gas Cap Venting

In 1992, Harley-Davidson went from a gas cap dual venting arrangement to a continuous venting system. The gas tank continuously vents while the gas cap now only vacuum vents fresh air in to replace draining gas. The gas tank(s) vent through an internal metal tube called a standpipe that connects to an external hose to allow evaporates to vent continuously. If removing the dash on the fuel tank(s), there may be two hoses or one hose depending on model.

One hose is an overflow that runs to the ground to allow gasoline to escape if overfilling the tank. To my mind, this is dangerous since I am always overfilling my tank and many times wind up with a puddle of evaporating gasoline underneath my hot motorcycle. Unfortunately, sometimes the gas will spill over my hot exhaust header pipe below the gas tank. I have to discipline myself to pay attention but my mind always seems to be thinking about a mechanical problem, analyzing something, or be simply floating along in a daydream. It seems that if I am on a customer bike, I always pay attention and give it the respect it deserves. On my own bikes, it is a different story.

1. The other hose connecting to a metal tube extending from the gas tank bung is the evaporative tube fitting that the hose connects to for continuous venting. This hose also connects to the vapor valve on both 49-State and California bikes. After the vapor valve, another hose vents evaporate into the atmosphere away from hot components while the hose leading from the vapor valve on California bikes feeds the evaporate into a charcoal canister for eventual purging back into the combustion chamber to safely burn as many harmful hydrocarbons as possible.

The 1992 and later gas caps will not work on 1991 and earlier models because they are for a continuous venting system and do not act as the evaporative vents themselves. There is a disassembled continuous venting gas cap picture in Volume III: *The Evolution: 1984 to 2000.*

Venting Safety for 1992-to-Present Evolution and Twin Cam Models

Mechanics and riders servicing their own bikes must pay attention to the routing of hosing; especially rubber hosing that serves as parts of the continuous venting system. With gas tank(s) removal and re-installation it is extremely important to ensure from a functional proper running motorcycle perspective that:

1. Vent hosing does not kink preventing free movement of air and evaporative gasoline.
2. Vent hosing does not clog up, again preventing free movement of gaseous air.
3. The vapor valve installs correctly in the up position or it will work opposite to the norm. *The longer thinner portion must face vertically up.*

4. The vapor valve is firmly attached to an immobile object like the frame center down tube to ensure proper continual working of the internal venting piston and spring.

From a safety perspective in order for a rider to enjoy the ride without impending danger it is important the continuous venting hose as well as an overflow hose are properly routed out of harm's way. Hosing must route and be tied off to prevent:

Contact with moving components that may frictionally rub a hole through the hose allowing vapor to escape. Friction also causes heat that may ignite vapor or the vapor may vent against an exhaust pipe or other danger spot.

1. Contact with the exhaust pipe, which will burn a hole through in a few seconds with possible dire consequences.

Donny's Blasts from the Past: **Fire Extinguisher; What Fire Extinguisher?**

I learn most if not all my lessons hard. Fortunately I pay attention to my school of hard knocks and do not repeat mistakes.

I am going back to the hardcore machismo days of the early seventies where bikers were men and women were double breasted. There was no room for anything else including sensitivity. Me and my bro Tramp were working on a 1947 Knucklehead chopper. The bike was a beauty with a raked frame, a real long front end with a skinny spool wheel without a brake or front fender. This was in a dirt floor garage in the city's seedy tenderloin where if you weren't strong you were a victim. Our dogs were big and mean as were we. I am sure the reader is getting the drift as me and Tramp lazily drank our beer on a hot Saturday afternoon while taking turns kick starting the radical beast that refused to start.

Tramp took the breather off the brass plumbing also known as a Linkert and held his hand over the carburetor's throat while I kicked away. This was done for what reason I do not know today, to choke the carburetor and put extra fuel into the lungs for the spark plugs to ignite. Of course, we could have just flipped the choke lever so the butterfly plate at the carburetor mount would block air to accomplish the same thing. This is just the way things were done back then. I guess if I bared my soul I would have to say that we really didn't have a clue but a real man could not admit that. Instead, we authoritatively fiddled with stuff like taking the breather off so we could convince ourselves and anyone else, particularly a woman looking on that we were on top of our game.

Back in those days, we didn't like the black gas line hose that also happened to be fire resistant because we could not see if there was gas in the line going into the carburetor. Yes, we had to be able to observe if the dreaded and omnipresent vapor lock was preventing gas flow. The automotive shops sold this line we all used that was clear hose that yellowed with use. It never occurred to us that the yellowing meant that it was not for use with gasoline. Details, we had no time for insignificant details. We were into big picture stuff; the stuff that really mattered, we were men of action who took bold steps even into the unknown. You know, I can make lots of fun of myself and the other hardcore riders of the day but to put this all into perspective, it would have been very poor judgment to question us or dare laugh at us back then...after all we were men of action. We knew only one direction and that was forward.

Anyway, Tramp removes his hand and there is lots of gas in the carburetor throat. As I continued to kick, there was air forcing back out of the carburetor throat mixing with the liquid gas. Today, I would kick once, see this and proceed to check ignition timing. Bikes used distributors with points and condensers back then. It was very easy to install the distributor so that the timing was 180-degrees out. When this happens, the bike can sometimes start and run with great difficulty but there is lots of backfiring especially back out the carburetor because the piston movement and valves are sort-of going in the wrong direction when the spark plug fires. If the plug is not firing, only a vapor backfires out through the throat.

However, if the spark plug is firing, sometimes the backfire would contain a temporary ball of fire that most times goes out because the evaporate gas in the air depletes. I finished a kick, with my leg still on the kicker pedal as I looked down at the carburetor. A ball of fire accompanied a backfire. This time it didn't go out as it found a fresh source of fuel. I couldn't believe my eyes. The momentary ball of fire burned through the clear hose substituting as a proper gas line in a fraction of a second. Gas poured out all over the side of the poor old Knucklehead feeding the rapidly spreading fire.

Where was the fire extinguisher? What fire extinguisher? We never took precautions. I grabbed a shop smock and tried to beat out the flames. I was pretty good at spreading a fire and not so good at putting one out. Tramp threw a bucket of water on the flames. The fire was now raging. I ran out of the shop and down the street to a local car garage, raced in, demanded where their fire extinguisher was and proceeded to rip it off the wall. I ran out without explanation, none was needed since it was sensible to sidestep a near-hysterical 275 lb biker with greasy hair half way down his back and a full beard obviously on a mission. By the time I raced back into the garage, the fire was still raging as black smoke from the burning tires choked me back. I fired off the extinguisher and got the flames out. The bike was burned to the ground. Nowadays, it would be a write-off but everything was rebuildable back then.

Tramp and I popped open a couple of more beers and surveyed the damages. Ahh well, luck was partially with us as my garage had cement block walls and a very high roof not the old dried out and rotting wood found in most garages in the area. Stoically, Tramp took a swig of beer and remarked the Knuckle needed a new paint job anyway. The good news was that we now had a major project to complete. We were progressively becoming more excited as we realized that we would be taking apart and rebuilding our first Knuckle engine. Our old ladies (wives) had now shown up. Tramp and I did not notice the successive eye rolls they were subjecting us to. We didn't care anyway. This was in an era where your bike and brotherhood was way more important than a girlfriend or wife. Half the trip back then was working on your scoot. It was as much fun as riding.

The lessons when working on a motorcycle are:

1. Use fuel line with a SAE (Society of Automotive Engineers) rating of SAE J1527, which became available after 1984.
2. No substance use or abuse.
3. Quality safe motorcycle components are a necessity of survival.
4. Always have the appropriate safety equipment in excellent condition and located in the proper place.
5. Always be prepared for an emergency.

Air Filtration

Air cleaners and the inside filtering material are one of the oft neglected but crucial components of a good running motorcycle.

Induction is all about the delivery of air for both an efficient running stock engine as well as the performance one. The basic tenet of power efficiency is air. Coincidentally, the same applies to engine efficiency. Gas cannot burn unless mixed well in differing proportions depending on need such as acceleration with the oxygen in the air.

Clean Air

Street bikes, whether performanced or not, have an expectation of longevity before a rebuild. Longevity to a conservative touring rider on a stock machine may well expect in excess of a hundred thousand miles before a major bottom end teardown.

Unfiltered air reduces engine longevity. Some particulate in the air may well burn in the combustion process preventing any harm. However, it is a guarantee that not all of it will. Some will adhere on cylinder walls forming an abrasive for the rings to push and pull up and down the cylinders. This unwelcome particulate may also settle on the cylinder bore below the ring lands wreaking havoc on wearing piston rings, piston skirt thrust surfaces and the cylinder sleeve itself.

Cylinder and piston material is relatively soft compared with other metals in the engine so these areas are particularly vulnerable. A smaller amount will blow-by the rings into the bottom end. Other particles may get between the valve and the guide. Dirt mixed with lubricating oil will form an abrasive that wears parts prematurely.

Proportionate Air

On a street bike, there is a potential problem with too much air for a particular size engine. Therefore, it is possible to have too big an induction system for some size engines although with Harley Davidson this is not a common problem.

The indicator of a performance filter performing is a resultant need to up jet the carburetor to allow more gas flow because of too much air relative to the supplied gas known as a lean condition.

Electronic fuel injection most times adjusts fuel delivery to air intake automatically via sensor information delivered to the computer ECM. However, an input or output ECM fuel modifier may need to increase the pulse width, which is the equivalent of up jetting a carburetor. Pulse width is the length of time the injectors squirt gas. This is a more practical alternative with minor power increases than actually replacing the injectors with larger ones.

Style over Function

I talk about style over function all the time. This occurs when an aesthetic look or sound dominates and eclipses the functionality of the part. In the wacky world of Harley Davidson, the conflict between perceived good looks, good sound, good whatever, and how well something performs many times is like the biblical fight between good and evil.

Evil wins out when some trick looking air cleaner makes its way onto a Harley that does not flow enough air for a mini-bike. This, of course will suppress existing horsepower.

We also must deal with other power suppressions like restrictive emissions controls. Speaking of which, all later Evolutions and Twin Cams have progressively more restrained power just waiting to be unleashed. The newer the bike, the more stifled power occurs. Emissions controls, which include the cams, exhaust, ignition, and fuel induction including the air cleaner and filter, repress power for the single-minded goal of meeting EPA standards in reducing emissions.

Evil will also win if the ultimate fashion air cleaner's filter is such poor quality and design that it lets lots of air through carrying lots of dirt. We need to filter the air entering the engine from a practicality point of view.

The filter design for a performance street bike need not impede air. It is possible to have the best of both worlds.

Dual-Vented 1984-1991 and Continuously-Vented 1992-up Sampling of Evolution and Twin Cam Gas Tanks and Gas Caps

<table>
<tr><td colspan="5">All 1991 and earlier single gas caps and right side dual caps vent both expanding vapors out as well as vacuum-venting in allowing outside air to replace draining gasoline.</td></tr>
<tr><th></th><th>1991 tank</th><th>1992 tank</th><th>1991 cap</th><th>1992 cap [1]</th></tr>
<tr><td>FXRS</td><td>61421-88A</td><td>61421-92</td><td>61102-83B</td><td>61272-92</td></tr>
<tr><td>FXLR</td><td>61006-87A</td><td>61006-92</td><td>61102-83B</td><td>61272-92</td></tr>
<tr><td>FXR/FXRT</td><td>61044-82C</td><td>61625-92</td><td>61060-82A</td><td>61273-92</td></tr>
<tr><td>FXRS-SP</td><td>61044-82C</td><td>61625-92</td><td>61060-82A</td><td>61273-92</td></tr>
<tr><td>FXRS-CONV</td><td>61044-82C</td><td>61625-92</td><td>61060-82A</td><td>61273-92</td></tr>
<tr><td>Dyna FXDB-S</td><td>61271-91A</td><td>61226-92</td><td>61102-83B</td><td>NA</td></tr>
<tr><td>Dyna all</td><td>NA</td><td>61226-92</td><td>61102-83B</td><td>61272-92</td></tr>
<tr><td>FLT all</td><td>61019-89B</td><td>61019-92</td><td>61091-88</td><td>61274-92</td></tr>
<tr><td>FXST 4.2 gal. right [2]</td><td>61218-85B</td><td>61052-92</td><td>61103-83B [3]</td><td>61271-92</td></tr>
<tr><td>FXST 5.2 gal. right</td><td>61211-84B</td><td>61053-92</td><td>61103-83B [3]</td><td>61271-92</td></tr>
<tr><td>FXST 4.2 gal. left</td><td>61237-91A [4]</td><td>61237-91A [4]</td><td>61103-83B [3]</td><td>61271-92</td></tr>
<tr><td>FXST 5.2 gal. left</td><td>61238-91A [4]</td><td>61238-91A [4]</td><td>61103-83B [3]</td><td>61271-92</td></tr>
<tr><td colspan="5">All 1992-to-present gas tanks are continuously vented for expanding vapors.
Similarly all 1992-to-present gas caps are vacuum-vented only allowing air to replace draining gasoline.</td></tr>
<tr><th></th><th>1999 tank</th><th>2009 tank</th><th>1999 cap</th><th>2009 cap</th></tr>
<tr><td>FLHR carbureted</td><td>61225-98</td><td>NA</td><td>61272-92B</td><td>NA</td></tr>
<tr><td>FLHRC(I) EFI</td><td>61268-98</td><td>61268-08</td><td>61272-92B</td><td>61272-92</td></tr>
<tr><th></th><th>2000-1 tank</th><th>2009 tank</th><th>2000-1 cap</th><th>2009 cap</th></tr>
<tr><td>FXST carbureted</td><td>62180-00A</td><td>NA</td><td>61272-92B</td><td>NA</td></tr>
<tr><td>FXST (I) EFI</td><td>61625-01</td><td>61625-08</td><td>61272-92B</td><td>61272-92B</td></tr>
<tr><td colspan="5">Gas tanks may functionally or stylistically change except for the continuously venting aspect, which remains constant. However, most vacuum-vented gas caps harkens back to 1992 even though most models did not begin to vacuum-vent only until 1994-1995.</td></tr>
<tr><td>Vapor valve</td><td>62150-85 [5]</td><td>62150-85 [5]</td><td></td><td></td></tr>
</table>

Gas tank part numbers are for unpainted but primed components.

NA = Not Applicable.

The FXDB-S Dyna Sturgis was the only production Dyna model manufactured in 1991.

[1] vacuum vented (late)

[2] Many H-D riders' especially older ones refer to the 4.2 gallon gas tanks as 3-gallon tanks. The 5.2 gallon tanks are referred to as 5-gallon tanks.

[3] dual-vented (early)

[4] Notice that the early 1984 to 1991 and late-1992 FXST left side gas tanks have the same part number indicating that H-D uses the same tank. The reason is that the right gas tank provides venting for both right and left side tanks. The right gas cap is vented, which allows gas to drain easily from the right side via the fuel valve (petcock). There is a gas equalizer hose connecting both tanks at the bottom front of each tank. However, this would not work unless the left side gas cap was also vented but it is not. There is a vent tube between right and left gas tanks at the top front to allow air to transfer from right to left, which will allow gasoline in both tanks to constantly equalize.

[5] All late continuously vented gas tank(s) have a rubber hose connecting to the internal vent-standpipe fitting, which may be on the filler cap bung or elsewhere that feeds into the one-way flowing vapor valve (62150-85) that allows vapor to evaporate into the atmosphere on 49-State bikes from a safe locale away from the hot exhaust pipes. In order for the vapor valve to open and close it must be affixed and remain stationary in the vertical upright position with the longer intake fitting upwards and the shorter outflow fitting downwards.

[6] Notice the vapor valve part number ends with the suffix -85, which indicates the vapor valve's first year of use. With gas cap venting use on 1984 to 1991 Twin Cam's, the vapor valve is not used on 49-State Harley-Davidson's. However on all Twin Cam's from 1985-to-present for use in California, the vapor valve is fed evaporate from the fuel tank and/or the air breather depending on year after the bike is turned off. The vapor valve then feeds these evaporate gases via another hose into the charcoal canister for storage and purging back into the air breather when the bike starts up and runs again. Negative pressures (vacuum) from the descending pistons and an almost airtight air box (breather) help bring evaporate back up from the canister. This is called purging and the evaporate returns for burning via the purge hose.

Please see Volume III: *The Evolution: 1984 to 2000* for detailed explanations of pre-1981 dual venting gas caps, 1992-to-present single vacuum-venting gas caps, and continuously venting fuel tanks along with pictures of disassembled gas caps showing the internal valve(s).

Crucial Filter Spacing

It is important for reducing the suppression of existing power that at least a quarter-inch of space exists between filter and the outer cover. We do not want to restrict air flow by scrunching the filter between housing surfaces. I cannot tell you the number of stock Harleys over the years that required jamming the outer cover up against the filter and then tightening the cover further against it.

The Environmental Protection Agency imposes two more duties on top of filtration and cfm (cubic feet per minute air) delivery on stock Harley Davidson filters.

The first is meeting emissions controls in terms of pollutants.

1. The second is to dampen air manifold noise; hence, no spacing between filter and housing for noise to travel around.

A stock filter is not the performance enthusiast's best friend.

Air Filter's: Year and Model

Year	EFI	Carburetor	FXST/ FLST	FXR	Dyna	FLT
1984	NA	Kehein	29259-83A	29259-83A	NA	29288-83
1985	NA	Kehein	29259-83A	29259-83A	NA	29288-83
1986	NA	Kehein	29259-86	29259-86	NA	29259-86
1987	NA	Kehein	29259-86	29259-86	NA	29259-86
1988	NA	Kehein	29259-86	29259-86	NA	29259-86
1989	NA	Kehein	29259-86	29259-86	NA	29259-86
1990	NA	CV Kehein	29259-89	29259-89	NA	29259-89
1991	NA	CV Kehein	29259-91	29259-91	29259-91	29259-91
1992	NA	CV Kehein	29259-92	29259-92	29259-92	29259-92
1993	NA	CV Kehein	29259-91A	29259-91A	29259-91A	29259-91A
1994	NA	CV Kehein	29259-91A	29259-91A	29259-91A	29259-91A
1995	NA	CV Kehein	29259-91A	NA	29259-91A	29259-91A
1995	MM	NA	NA	NA	NA	29291-95
1996	NA	CV Kehein	29330-96	NA	29330-96	29330-96
1996	MM	NA	NA	NA	NA	29291-95
1997	NA	CV Kehein	29330-96	NA	29259-93	29259-93
1997	MM	NA	NA	NA	NA	29291-95
1998	NA	CV Kehein	29330-96	NA	29259-93	29259-93
1998	MM	NA	NA	NA	NA	29291-95
1999	NA	CV Kehein	29330-96	29055-89	29461-99	29461-99
1999	MM	NA	NA	NA	NA	29462-99
2000	NA	CV Kehein	29461-99	29055-89	29461-99	29461-99
2000	Delphi	NA	29461-99	NA	NA	NA
2001	NA	CV Kehein	29461-99	NA	29461-99	29461-99
2001	MM	NA	NA	NA	NA	29462-99
2001	Delphi	NA	29461-99	NA	NA	NA
2002	NA	CV Kehein	29461-99	NA	29461-99	29461-99
2002	Delphi	NA	29461-99	NA	29461-99	29461-99
2003	NA	CV Kehein	29461-99	NA	29461-99	29461-99
2003	Delphi	NA	29461-99	NA	29461-99	29461-99
2004	NA	CV Kehein	29461-99	NA	29461-99	29461-99
2004	Delphi	NA	29461-99	NA	29461-99	29461-99
2005	NA	CV Kehein	29461-99	NA	29461-99	29461-99

2005	Delphi	NA	29461-99	NA	29461-99	29461-99
2006	NA	CV Kehein	29461-99	NA	NA	29461-99
2006	Delphi	NA	29461-99	NA	29461-99	29461-99
2007	Delphi	NA	29461-99	NA	29461-99	29461-99
2008	Delphi	NA	29461-99	NA	29191-08	29633-08
2009	Delphi	NA	29461-99	NA	29191-08	29633-08
2010	Delphi	NA	29461-99	NA	29191-08	29633-08

MM = Magneti-Marelli electronic fuel injection (EFI); 1995 to 2001 FLT Touring. Delphi EFI began in 2000 with the Softail models.

NA = Not Applicable since Dyna models did not begin production until 1991 and FXR models ceased production in 1994 but resumed as the first three Screamin' Eagle CVO models in 1999 and 2000. Furthermore, Magneti-Marelli EFI did not introduce until 1995 on the FLHTCUI Ultra Glide Classic. In 1996 The FLHRI Road King, FLTCUI Ultra Tour Glide Classic, and the FLHTCI Electra Glide Classic introduced. In 1998 the FLHRCI Road King Classic, FLTRI Road Glide, FLHRPI (FLHPI) Road King Police, and the FLHTPI Electra Glide Police introduced. All other Evolution models were carbureted. Magneti-Marelli continued as the EFI induction until the end of 2001 on FLT Touring models when Delphi EFI took over exclusively for EFI fuel delivery until present day. Delphi EFI made its debut on 2000 Softail fuel injected models and continue to present day. The CV Kehein carburetor ceases use after 2006 on all models. Delphi EFI begins use on all models including Sportster in 2007.

Cleaning Air Filters

Consult your manual for the maintenance schedule for particular year and model. If using an aftermarket filter follow the instructions given by that manufacturer.

Maintenance Schedule

However, it is prudent to service the air filter after 1000 miles (1600 km), and every 5000 miles (8000 km), thereafter *in normal riding conditions* although some manuals may recommend longer periods in between.

1. Service more often if riding in the rain frequently.
2. Dirt roads or dusty riding conditions require more numerous inspections, cleanings, and/or replacements.
3. Symptoms of dirty filters are:
4. Hard starting.
5. Anemic performance.
6. Poor gas mileage.
7. Yes, there are other conditions that may exhibit the same symptoms, but I always proceed with easy fixes that are inexpensive and progress to the more complicated and costly ones. This is so obvious and logical. However, the nature of many Harley riders and mechanics that should know better is to bypass the obvious and diagnose the most expensive, time-consuming fix right out of the gate. Many times, after much money is spent and time consumed, both mechanic and rider realize the cause is something simpler. It takes minimal time and effort to eliminate the air filter as the cause of the above noted symptoms.

A dirty filter may restrict air enough to cause a rich condition that will use more gas and can ultimately foul spark plugs. Increased gas relative to air feeds into the combustion chamber. This decreases mileage because of inefficient burning of the fuel. Excess gas discards out the exhaust as unburned or partially burned pollutants. Furthermore, if the condition becomes too rich, the excess gas may foul the spark plug(s) with a flat black fluffy residue preventing the spark from arcing between plug electrodes.

As I said, a clogged filter restricting air-intake might also cause hard starting. After checking the filter, we can go onto progressively more complicated diagnosis for hard starting. For example on a bike with electronic fuel injection, check the idle air control (IAC), for incorrect positioning at rest. If the IAC positions wrongly, it will send the wrong information to the electronic ignition module. This easily happens if it gets sticky and does not set to the position dictated by the ECM. Incorrect IAC position will result in the wrong amount of air delivery at closed throttle and one symptom may be hard starting.

Another very common cause may be disturbed or leaky manifold rubbers, again upsetting the air balance resulting in a symptom of a hard starting. I mention all this to show how complicated some people can make a simple problem in bypassing a potentially dirty air filter.

- How can performance and engine efficiency be what is expected with restricted air-intake?
- Lastly, how can gas burn at a high percentage rate when the air catalyst for ignition is lacking?
- Many times, the simple maintenance, so important to a functioning motorcycle and crucial to a high performance one is lacking. I watch so many spend big money on super-duper engines that fail to ensure clean filtration, proper tire pressures, belt and chain adjustments and on it goes. More than once, I beat performance bikes not maintained correctly, in impromptu races with a stock but well cared for Harley.

A Simple Trick

A simple but effective trick if the bike is equipped with a round air filter is a scheduled rotation procedure. One section will get dirty faster than the rest of the filter, as there will be a *sweet* spot for more air intake. Rotating a round filter will extend its life and keep the whole filter cleaner for a longer time-period. This can also be done in a limited way with rectangular air filters

Air Filter Materials

Anyone interested in an efficient running engine never mind a performance one will use the best and widest pleated filter available that both filters the air and allows sufficient volume to supply adequately the size engine served.

This is the easy part. Skilled people like Tim Doherty of Doherty Machine (www.dohertymachine.com) concern themselves with the difficult physics of controlling the volume of air once past the filtration stage. Tim explains "...in reference to flowing more air and I make this reference with strong and proven conviction, an air cleaner is simply what the name implies, it's an *air cleaner* and any given engine will benefit by installing an air filter capable of supplying a specific engine's air requirements. The key to this entire matter is realizing that and an air filter is simply that a *filter*. Removing the stock restricted filter and using a bath towel could in simple terms accomplish air mass and the filtering process. The key to air filtration is controlling the air once it passes the filtering stage." [4] Thus, the air cleaner has three functions:

1. Filter airborne dirt particulate.
2. Allow sufficient cfm volume through the filter.
3. Control the air flow stream after filtration.

The uses of four basic products formulate most air filters:

1. Foam.
2. Paper.
3. Synthetic media.
4. Natural cotton gauze.
5. In Evolution models, Harley-Davidson uses foam from 1984 to 1986; 2-stage foam from 1987 to 1992, and pleated paper encased by metal sides from 1993 to 1999. Synthetic media finds use during the transition from Evolution to Twin Cam engines and continues present day.

Increasing the Filtering Surface Area

Pleating paper as well as synthetic media along with layering gauze is a common design feature used to gain more surface area from which the air can penetrate and pass through. All three have a myriad of different size holes in the filter material to trap particles of dirt. Pleating offers another advantage with increasing the number of entrapment holes. More holes will be available with more filter surface area.

Single Layer Filtration

A single paper or gauze layer will trap dirt particles that are larger than the hole they attempt to enter. A problem arises when the particle of dirt is smaller than the hole as it will obviously get through. Once a hole captures a dirt particle it plugs. Fortunately, there are a great many holes. As a high percentage of the holes plug, the now dirty filter becomes restrictive and does not allow enough air in. Hence, the needs to either wash or change filters.

Foam Filter Elements

Foam, natural cotton, and synthetic media air filters often use oil as a capture agent. Therefore, if minor engine blow-by occurs especially on 1992 to 1999 Evolutions and later Twin Cam models it can actually assist in filtration.

Foam filters can be very superior to paper filters or they may be more restrictive especially in performance applications where engine vacuum can suck both types inward. It is important to purchase filters from reputable shops and manufacturers to avoid a restrictive air flow foam filter.

In theory, a foam filter should and usually will filter better than a single layer paper one. The following explanation will demonstrate the superiority of a properly made foam filter over a paper one.

- Paper filtering holes are a straight run for air-laden particles where luck of the draw dictates a smaller particle will pass through a larger hole.
- Foam filters actually have very large holes but capture particulate in a different way.

If the larger holes were a straight passage, the foam filter becomes useless. The foam filter holes are not straight at all but wind their way through the foam in many directions. However, the larger hole-design is to ensure all the dirt is able to enter.

Traveling dirt in the air hits a wall when the tunnel hole changes direction; the impregnated oiled filter will grab onto the dirt and hold it.

1. Since the holes are large, more dirt can enter and the already captured particulate, soaked in oil will assist in the new capture.
2. If dirt makes it, around one or more bends another is likely to capture it.
3. It is difficult for the dirt to make it all the way through especially with the sticky oil-filtering agent.

The single flat paper element holes capture one particle each and clog. The foam filter holes may capture many particles before clogging becomes an issue.

Cleaning a Foam Air Filter

The foam filter is reusable after washing in solvent and re-oiled according to manufacturer specifications.

1. Remove the foam filter from the support wire mesh.
2. Clean with soap and water.
3. Allow to dry.
4. Evenly apply about 1.5 ounces of 20W-50 engine oil.
5. Work the oil through systematically and squeeze out any excess oil.

Paper Filter Elements

Paper swells with high humidity moisture and likes rain even less. This restricts air traveling through the filter. Furthermore, the sucking force of engine vacuum on a moistened paper filter element may cause embedded, captured dirt to further clog when the paper dries out. Have I talked the reader out of paper filters yet?

Actually, paper is not that bad for smaller *workhorse* engines where performance is not a prime consideration. Some good filters for these type engines use paper although my personal preferences are multi-layered cotton gauze or synthetic media. Paper usually has a single layer while gauze has multiple interwoven layers. Paper filters have relatively small filtering holes. This is necessary to capture a higher percentage of particles because smaller specks of dirt can pass unhindered through larger filtration holes. Therefore, cfm (cubic feet per minute) air delivery may restrict for larger demands.

Paper filters *surface load* dirt. The surface of the paper filter traps and captures particulate. Reputable and knowledgeable air breather manufacturers like Tim Doherty feel that the type of material is not that relevant to performance increases as long as the cfm rating is the same requirement for the size engine served. Of course, Tim's high flow filters use the best of filtration-pleated materials, which does not include paper. I think adequate paper filtration is incapable of high cfm ratings required on many of today's monster engines. On the other hand, it is sufficient for stock Evolution engines but synthetic media filtration is the preferred choice for Twin Cam engines.

The Perfect Marriage of Filtration and Air Flow

The perfect marriage is the necessary ability to remove particulate from the air along with substantial cubic feet per minute (cfm), air delivery. The goal is to protect the engine from dirt while feeding it ample air for intended performance capability.

Wide or Narrow Air Filters?

Another factor I will discuss many times is the surface area of the filter. How can a pleated one-inch wide filter compare with say, a Doherty filter that is pleated but 2 ¾" wide? Furthermore, check out the width of some S&S Cycle, Inc. performance pleated filters. They are all business. Do not use a thin filter when a wider one is available as the thinner one may restrict cfm delivery.

Oil Impregnation of Paper Air Filters; 1992 to 1999

Occasionally, a paper filter may be oil impregnated from blow-by gases not properly separated by the breather apparatus in each head from 1992 to 1999. Oil is supposed to separate internally, inside the engine from venting gaseous air but this is not always a perfect world. If there is oil in the paper element, discard it and install a new filter.

Maintenance Examination of a Paper Filter

To check a paper filter like those used in Harley-Davidson Evolution models, hold it up to the sun or a bright light. Look for a visible, consistent, and uniform permeation of light through the filter. If not, the filter needs cleaning. Unlike most paper filters, the H-D one is cleanable.

1. Do not wash a paper filter element in solvent.
2. Gently wash in warm soapy water.
3. Let it soak for around a half-hour to remove soot and particulate.
4. The filter element may be air-dried.
5. If using compressed air to dry the filter; gentle and low pressure (32psi) is the key.
6. In order to remove dirt particles, blow air from the inside out. If blowing from the outside, there is a risk of further embedding dirt particulate.
7. Do not put oil on a paper filter to assist as a filtering capture agent.
8. Do the sun test once more.
9. If the filter fails a uniform sun penetration test, discard it and install a new one.
10. Clean the breather connectors.
11. Clean the air cleaner cover and back plate from residue oil and carbon.

If a new purchase is required why not upgrade to a superior natural or synthetic media flowing filter, with more surface area.

Natural and Synthetic Media Elements

Like paper elements, the filtering holes in natural and synthetic media elements are mostly straight through and of different sizing. However, the comparison between paper and media ends with this similarity. The cotton gauze used by aftermarket and OEM supply companies such as K&N can easily flow two or three times the air than paper can. This is a generalized blanket statement designed to demonstrate the superiority of layered cotton gauze or synthetic media over paper. There are other parameters like how big the comparative filters are as well as the number and depth of pleats. This dramatically affects surface area that will determine the actual percentage superiority.

- In order to filter air adequately, paper must be thick or conversely densely compressed otherwise particulate will easily traverse the material.
- Unfortunately, this makes paper more restrictive to air flow.

Then the paper progressively clogs as it collects particulate. A pressure differential begins to occur.

Pressure drops inside the filter whilst remaining at atmospheric pressure on the outside.

- In extreme cases, dirt will forcefully suck through the filter and into the engine.

Thus the importance of having a clean paper air filter at all times.

These natural filter elements are usually cotton gauze layers overlaying each other. Synthetic media filters perform much the same process but with manmade materials. The overlays assist in capturing more particulate because the holes of successive layers do not line up with each other. The same situation occurs with the random sizing of the holes. Once again, filter oil can act as an effective capture agent although some do not use oil. Consult your manual.

K&N (www.knpowersports.com) is perhaps the best-known supplier of filters and they have excellent choices for your bike. Many use a 4-ply natural cotton gauze material. The advantage is the very small natural filtering fibers that make up cotton gauze that traditional paper and foam have difficulty in replicating.

- Layered-gauze does not surface-load trapped dirt like paper.
- Instead, the natural cotton gauze and some synthetic media filters exhibit *depth-loading* characteristics where retention of filtered dirt particles is multi-level throughout the different layering.

The theory of capturing particulate gets a little more complicated as we look at the characteristics of flowing air and its ability to carry dust and dirt.

1. Interception is the first concept.
    - Air flow like water will always take the shortest, fastest, and most direct pathway.
    - As the air flow travels around the small cotton fibers seeking passageways through the filter, some of the airborne particulate will make contact with the fibers.
    - The oil-impregnated fibers will arrest (capture) these particles.
    - There may also be a tacking material in some synthetic media filters fulfilling the same capture function as oil.

Unlike smaller, lighter airborne dirt that unequivocally follows in the air flow, larger, heavy particulate have their own physical properties where inertia and momentum cause them to deviate from turning air flow.

1. The concept of impaction or collision comes into play.
    - The larger particles momentum forces them to deviate from the air stream as the air turns seeking the shortest path of least resistance through the cotton gauze.
    - As the air turns, the bigger particles keep going straight and collide head-on with the capturing oiled fibers.
2. Air velocity and small particulate:
    - The smallest particle dust will behave differently from small and large particulate.
    - Within an air stream, there may be velocity differences; changes of direction and of course, pressure adjustments.
    - Dust lacks momentum and inertial qualities to combat or deviate from these forces.

- The dust particles will appear to have frenzied and haphazard behavior going in complete disorder within the air stream. They too will collide with the fiber media whose oily capturing agent will collect them.

This effectively captures particulate much smaller than the larger pathway holes through the media.

Cleaning Natural Cotton Air Filters

Cleaning natural cotton fiber filters is easy and they are reusable.

Do not use compressed air to clean them as filter material can blow out of the surrounding wire mesh, thereby ruining the filter.

1. Also, do not scrub the wire mesh with a brush to remove sediment as the cotton gauze tears easily.
2. These filters are washable, may be re-oiled, and are reusable like foam ones.
3. These filters should dry naturally
4. They are unaffected by moisture.
5. Gauze filters may be assisted by minor oil blow-by from engine breathing.

Cleaning Synthetic Media Filters

Synthetic media like filter OEM 29330-96 is used primarily on 1996 to 1999 Softail Evolution models. Of course, most if not all Twin Cams use this superior type air filtration.

- Clean the air cleaner cover and back plate from residue oil and carbon.
- Wash air filter element and breather tubes with lukewarm water and mild detergent soap. Soot and carbon buildup; soak in the warm water and detergent for 30 minutes.
- Dry with compressed air from the inside out with no more than 32psi (220kPa).
- Direct compressed air through the breather tubes and connectors to ensure cleanliness and free passage.
- Visually inspect for wear, cuts, holes etc.
- Also clean air cleaner cover and back plate from residue oil and carbon.

Aftermarket Filters and Motorcycle Warranty

Can a manufacturer void their motorcycle warranty unless their air filter is used? Furthermore, does an authorized dealer have to install the air filter for warranty reasons? As with oil and oil filters, this is a common scare tactic, when used to force customer loyalty.

The United States passed the Magnuson-Moss Warranty Act in 1975 whose statute governs warranties on consumer products. Named after its sponsors, United States Senator Magnuson and Senator Moss, most other western countries have followed suit with variations of this consumer protection law. According to the Report of the House of Representatives, which accompanied the law, Congress enacted the Magnuson-Moss Act in response to the widespread misuse by merchants of express warranties and disclaimers. The legislative history indicates that the purpose of the Act was to make warranties on consumer products more readily understood and enforceable and to provide the Federal Trade Commission with means to improve protection of consumers. [5]

There is no law to force manufacturers to give a warranty on consumer products. However, if a warranty is given, which Harley Davidson obviously does, it must comply with the

Magnuson-Moss Warranty Act. This law states in part that it is against the law for a vehicle manufacturer to mandate the use of a specific air filter, oil filter or oil unless it *provides these items free of charge!* The manufacturer, however, can insist on adhering to their specifications with aftermarket replacements of filters and/or oil, which is fair.

When I first started wrenching in the late sixties, I think replacement quality was a concern. There were filters, whether it was an air or an oil filter, that were substandard and the same concern applied to oil. Brand name air/oil filters and oil are all of superb quality these days.

A few years ago at American Iron Magazine, we tested numerous oils, both fossil and synthetic to find out the best one for a Harley Davidson. They were all excellent including the H-D proprietary oils. Some were better than others were but only by small degrees, any would do your bike proud and none tested would cause harm.

The performance filters discussed in this article as well as a host of others on the market are of the highest quality in filtering capacity and the ability to flow high velocity and therefore high volume air.

Carburetion Types and Principles

Carburetors are all about pressure differences whether caused by the weight of air (atmospheric pressure) or by vacuum (less or negative pressure relative to atmospheric pressure).

Vacuum or negative pressure may result from a venturi design basing on Bernoulli's Principle or by rapidly descending pistons or by higher rpm *scavenging* also known as the physics Principle of Momentum.

Without these differentials in pressure, carburetors could not function at al

Gasoline Cannot Burn without Air

To state the obvious; gasoline cannot burn by itself. Gasoline needs to combine with air in order to burn.

Pressure differences direct air flow as well as vaporized fuel via principles of physics that cannot be changed or violated.

- Internal engine design changes rapidly in tandem with ever increasing governmental emissions dictates that attempt to achieve complete combustion.
- More air relative to gas very effectively decreases harmful emissions.

The Butterfly Throttle Plate

Most motorcycles use one of three types of carburetors.

1. Butterfly carburetors.
2. Slide control carburetors
3. Vacuum controlled carburetors

The butterfly type is the H-D vernacular for a flat circular disc that pivots or butterflies in the carburetor throat, opening or closing to control air flow through the venturi. The H-D butterfly carburetors include the Schebler, the famed Linkert, the rare DC Linkert (1966), the much-maligned Tillotson (1967-1971), Bendix (1972-1975), and the Kehein (1976-1989) not to be confused with its successor and the last carburetor in use on a Harley-Davidson, the CV Kehein (circa 1989 to 2006). Butterfly type carburetors like those listed above powered Harley Davidson's from the early nineteen hundreds until 1989. The hybrid CV Kehein uses a butterfly plate in conjunction with a vacuum-operated variable-venturi slide. The aftermarket supplies many types of butterfly type carburetors also like the S&S Super B, E and G.

A throttle cable connects directly to the butterfly shaft that holds and rotates the internal butterfly circular plate disc in position via a lever mechanism on the outside of the carburetor. When the butterfly closes, air flow severely limits, which stops any venturi action. The butterfly is not set to close 100% because this position chokes off all air entry. A little air is required for idling. As the twisted throttle opens the butterfly, air and fuel correspondingly increase in flow to create more engine power.

No One Ever Explains the Venturi

Publications always refer to the venturi. However, no one ever seems to explain what a venturi is or the physics principle that it relies on.

- The venturi is part of the carburetor throat.
- The throat is the opening through the centre of a carburetor.
- Bernoulli's (Physics) Principle comes into play here.
- Mechanics may call Bernoulli's Principle the Venturi Principle as a descriptive way to get away from the guy's name that first recognized this universal physical law.

A venturi is a restriction or more correctly, a narrowing formed in the carburetor throat that causes an increase in the velocity of air. Think of a wide lazy river as it narrows. The water must speed up in order to pass the same volume through the narrowing in the same amount of time. The weight of the water behind forces the increase in speed…ditto for air in a venturi.

Vacuum's Many Induction Roles

If I describe this in another way, the increase in air/fuel velocity through a venturi also causes a vacuum increase (decrease in pressure), as the air passes through.

- This pressure difference draws fuel through jetting from the connecting float reservoir and into the air stream.
- If looking at slow moving air (low vacuum), on one side of the carburetor throat, it speeds up as the same volume must get through the narrower venturi in the same period of time thus creating high vacuum or suction, which draws in the gas.
- The gas begins to atomize as it draws into the fast moving air flow.
- After passing through the venturi, the air enters the manifold and into the intake port to draw into the combustion chamber via another vacuum created by descending pistons.
- Valve overlap creates a different origin vacuum at higher rpms that draws in the fuel mixture into the combustion chamber via the physics principle of Momentum also known by the mechanical term *scavenging*.

Slide Control Carburetors

The second type of carburetor, which is not in use on a Harley except in the aftermarket, is a slide control. The throttle cable activates the slide. The older Mikuni's are a good example of this.

Vacuum Controlled Carburetors

The third type is vacuum controlled carburetors like the circa-1989 to 2006 CV (constant velocity) Kehein that use both a slide and a butterfly to control air flow through the venturi.

The throttle cable does *not* attach to the slide but to the butterfly.

- Vacuum acting on a piston and diaphragm operates the slide on these carburetors like the CV Kehein.
- The difference with the CV carburetor is the vacuum piston controlling the opening size of the venturi.
- This is a precision mechanism that controls air and gas flow via vacuum.
- The sole butterfly semi-rotating plate methodology located inside the venturi on H-D predecessor carburetors like the 1976 to 1989 Kehein is wasteful, inefficient, and disruptive to air flow.

Basic Carburetor Tuning

Do not confuse other carburetor or mechanical problems with a jetting situation. For example, a tuner can jet forever but this will not resolve a severe manifold air leak. The tuner may be able to adjust jetting to resolve a minor air leak by compensating more gas for the extra air intake but this will only create problems in other areas that will become very frustrating.

1. First, tune each circuit for its primary function to create a base line.
    - One, adjust the idle jet and fuel mixture screw for the best idle.
    - Two, set the main jet for best wide-open throttle.
    - Three; regulate the needle for steady cruise with light throttle (CV Kehein).
    - It can take a Harley twenty miles of riding in order to reach operating temperature for fine-tuning purposes. In addition, temperature and air density can vary greatly from morning to afternoon sun to dusk

If experiencing jetting related ride-ability problems, attempt to replicate the problem in all gears and observe during temperature changes day-to-day or morning to afternoon. This will provide clues as to which circuit needs tuning whether it is:

Idle or light throttle, which will require slow speed jetting and a mixture screw adjustment.

1. Steady throttle and/or light acceleration, which will require a needle correction (CV Kehein)
2. On a Kehein carburetor the throttle butterfly plate covers the mid-range port until the throttle is twisted thereby opening the throttle plate and automatically opens the mid-range port.
3. Finally, wide-open throttle/hard acceleration, which will need a main jet adjustment.

Decide if the carburetor is running with too rich an AFR (air-fuel-ratio) ratio or a too lean AFR.

If the problem is aggravating when hot, this is a too-rich symptom.

- If the problem is irritating when cold, this is a too-lean symptom.
- If the situation worsens in higher gears, this is a too-rich symptom.
- If the situation worsens in lower gears, this is a too-lean symptom.

Make only one adjustment at a time to isolate the problem! After making an adjustment, attempt to duplicate the problem again.

There are tricks that may make the tuning process easier and faster. For example, if suspecting a main jet mal-adjustment it will probably be easier to test for a rich or lean condition first. In this case, remove the air filter if you think the jetting is too rich. More air entering the carburetor will lean out the rich condition. Duct tape up to a half of the filter surface area of the air filter surface if suspecting a lean condition. Less air entering the carburetor will richen the lean condition. Sometimes just removing the air filter and holding your hand over the carburetor throat will steer the tuner in the right direction.

Once knowing the direction of jetting change or adjustment, the severity of the problem will indicate a starting position for the adjustment.

These simple tests may complicate another circuit temporarily.

- The tuner should ignore these symptoms, as they are not permanent.

Screamin' Eagle 40mm Carburetor

I am not a big fan of this first H-D performance carburetor. It has a butterfly-plate type throttle, which is not impressive from a performance perspective. The Screamin' Eagle 40mm carburetor (91731-85, 91731-85A, 91731-88) went through many improvements in attempts to correct a variety of annoying hiccups.

Many had a vexing problem of attempting to maintain a smooth idle. Jetting was not the answer although this is the solution pursued by most. One source of a varying idle malfeasance was an incorrect accelerator pump rod length. The correct length is 2.540" to 2.550".

The CV Kehein Carburetor: 1989 to 2006

Do not confuse the 1976 to 1989 *fixed venturi* 38mm Kehein carburetor with another totally different carburetor, the circa 1989-1990 to 2006 *variable venturi* 40mm CV Kehein. The name Kehein is that of the Japanese manufacturer.

A huge improvement began in MY (midyear) 1989 Harley-Davidson production with a 40mm constant velocity (CV) carburetor replacing the relatively inefficient butterfly-throttle type carburetor that was in use forever in a variety of styles. The predecessor Kehein butterfly plate channels air and fuel into the manifold and head ports but has the disadvantage of disrupting flow, slowing down the intake charge.

The Kehein discontinues in favor of the CV Kehein on all models by 1990. The CV version's slide rises up and down in the venturi. Various laws of physics basing on vacuum raise and lower the slide thus varying the venturi size allowing the constant velocity of air and thus fuel. This eliminates many of the hiccups of the fixed and overlapping circuits of a butterfly type carburetor.

The move to the CV was to appease the EPA diminishing emissions dictates. However, protecting the environment can also have wonderful effects for the H-D rider in terms of fuel conservation and fuel delivery. Another result is more reliability. The Harley rider also loves the upshot of lots more speed with CV usage. The 40mm size is capable of delivering more fuel and air than the 38mm predecessor. Horsepower figures for models utilizing the CV go up from their predecessors. It is the best carburetor ever to grace a stock production Harley-Davidson. It can service mild performance increases and modify for wilder hop-ups.

Honda Components on Harley-Davidson Motorcycles

Kehein is a subsidiary of Honda, Harley-Davidson's supposed archenemy. This is not the first or last times those subsidiaries of Honda or other Japanese companies supply the Motor Company.

In 1974, H-D begins use that continues to present day of suspension parts like the front forks manufactured by another Honda subsidiary named Showa!

- A company named Kayaba made the narrowglide front end forks in 1973.
- Then there is the Hitachi starter motor that supersedes with the Nippodenso starter motor in 1989.

The bottom line is that the CV is a wonderful carburetor but not as efficient as its successor, electronic fuel injection (EFI). It is one of the few carburetors that attempt a response to altitude changes. It is partially successful in that the pressure difference in the upper and lower chambers reduces as elevation increases. Therefore, less fuel delivers because of the pressure reduction.

As altitude increases, atmospheric pressure decreases, which is the fancy way of saying there is less air available.

- Conversely, the pressure difference in the two chambers, upper and lower, will increase as elevation decreases towards sea level.
- More fuel will deliver because of the pressure increase. The CV Kehein carburetor is:

1. Constant velocity.
2. Gravity fed.
3. Uses a float operated inlet valve.
4. Variable venturi via slide action.
5. Has a throttle stop screw for idle speed adjustment.
6. There is a fuel enrichment system for starting.
7. Idle and transfer ports provide a balanced fuel mixture during the transition period from idle to mid-range.
8. A vacuum piston controls the venturi opening.
9. Has an accelerator pump.
10. The accelerator pump system uses sudden throttle openings (rapid acceleration), in order to rapidly squirt fuel into the carburetor venturi to provide the extra fuel necessary for smooth acceleration. Aggressive throttle twisting activates the accelerator pump.

However only the first third of complete throttle travel pushes the accelerator pump rod down, which flexes a diaphragm.

- Earlier model H-D carburetors like the Bendix (1972-1975) outfitted with accelerator pumps use a rawhide or rubber cup as opposed to a diaphragm to force or squirt the gas into the venturi in a steady airborne stream.

- The check valve stops any back flow of gas during this downward accelerator-pump-rod-stroke.
- A spring returns the diaphragm back into its original position.
- Gas then flows from the float bowl reservoir underneath the diaphragm via pressure differentials in order to replenish for the next handful of throttle twisting.

Carburetion gas delivery accomplishes through another physics principle, gravity from an overhead-located gas tank.

Enriching a Cold Start

There are three methods of choking or enriching the air-fuel-ratio on a Harley-Davidson. All three have use on the Twin Cam.

1. The choke butterfly plate (1984 to 1989 Kehein) that restricts air into the venturi in order to provide a richer mixture (more gas relative to air) in all previous H-D carburetors is crude when comparing to the CV enrichment system.
2. Like the operation of most butterfly choke plates, the CV Kehein (1989-1990 to 2006) enrichment circuit controls by a knob and linking cable that locates under the gas tank on the left hand side of a Harley while sitting on it.
3. The more sophisticated Magneti-Marelli EFI (1995 to 2001) does not need either enrichment or choking systems as the computer microprocessor dictates pressurized-fuel needs to the fuel injectors via information provided by sensors.
4. Early usage of the CV Kehein did not involve a comprehensive tie-in sensor feeding microprocessor controlling engine management system. Today's carbureted Harleys until their last year in 2006 have engine management that is very sophisticated but still cannot achieve the levels of fuel economy, emission control and even performance that later Twin Cam Delphi EFI broaches.

Assisted cold starting evolves from the use of traditional and crude butterfly choke plates to a more sophisticated enrichment circuit to the current and ultimate sensor fed computer.

The CV enrichment knob can pull out incrementally to a full position depending on temperature and altitude. Manuals instruct not to turn the throttle at all when utilizing a carbureted enrichment system. Nice try! Harley riders on carbureted bikes will never seem to learn not to touch the throttle. Surveys report within a margin of error of plus or minus one that nine out of ten Harley riders surveyed believe throttle blipping is a necessary ritual act of domination. Those riders that have EFI equipped Harleys quickly learn not to blip the throttle as they patiently watch for the fuel pump EFI indicator light to go out that locates on or near the speedometer face.

Manuals instruct all kinds of rules for how long to leave a carburetor enrichment device on. They have instructions for hot engines, for cold engines, and instructions combining with distance rode and/or time to leave the device on.

My suggestion is to use these instructions as a starting point if you are a novice H-D rider. However, these seemingly inanimate machines all have their own peculiar personality traits. Starting procedures will vary from bike to bike. Experiment and the bike will not be afraid to voice its displeasure until it purrs in a potato-potatoey sort of way.

If the enrichment knob is in the wrong position the bike will immediately react by idling poorly either because of not enough gas or too much gas.

- The same goes with acceleration and cruising.

Why is this so complicated when the system is so sophisticated?

Lean emission dictates are fooling with the laws of physics so they must compensate with more gas (enrichment) to combat too much air.

- These engines do not want to run initially because the air/fuel mix is way off for cold starting situations.
- Once the engine warms to operating temperature, it is easier to ignite these super lean (more air relative to gas), mixtures.

On my own bikes, I pull the enrichment device full on, start her up, and begin to push the knob slowly back in.

- If the bike stutters, I pull it back out.
- If it is bogging down, I keep slowly pushing the knob in turning the enrichener off.
- It is no big deal; after awhile, it becomes second nature.

The enrichment (starter valve) device;

1. Meters fuel upward through a valve chamber.
2. The starter valve opens a passage into the carburetor venturi on the vacuum side.
3. Air also directs to the valve chamber to mix with the gas.
4. The descending pistons on their downward intake stroke cause a vacuum (low pressure).
5. Gas from the float bowl chamber will draw up into the carburetor venturi by the pressure differentials caused by the venturi effect and the descending pistons that create negative pressure.
6. The lower pressure in the venturi causes the now higher pressure in the float bowl chamber to force the gas to ascend into the lower pressure area.

Cold Weather Starting the CV Kehein

It seems that the Harley rider was having initial starting and warm-up procedural issues with the then new CV Kehein constant velocity carburetor. Unless, involved with hi-performance carburetors like the Mikuni, the CV Kehein was a brand new experience for H-D riders who were raised solely on previous butterfly throttle plate carburetors.

The Factory found it necessary to issue a Service Bulletin (M-1005) on November 13th, 1990 titled *Cold Weather Motorcycle Operation* to teach the vagaries of this best carburetor ever used on a Harley-Davidson. Of course, the H-D rider blamed this Japanese piece of crap for problematic starting instead of adapting to new technology. It mattered not that much of the information in the Service Bulletin was also found in the Owner's Manual issued with each new motorcycle under *COOL ENGINE* starting instructions. H-D defines cool weather as an outside temperature cooler than 50° F. The procedure delineated by H-D is:

1. Ensure throttle is closed.
2. Pull enrichener knob all the way out (full-out).
3. Turn ignition on.
4. Press starter button to operate electric start. Bike should start.

Before I continue, let's look at the problem. The rider must *not* touch the throttle. As I have said, this is next to impossible for an H-D rider to do before the advent of EFI. Herein lies the problem since throttle activation at anytime during the starting procedure will:

- Actuate the accelerator pump.
- Disable the enrichener system.

This was the first and only H-D carburetor to have an enrichener system. It is baffling to many riders. Those who had experience with S&S carburetors knew not to touch the throttle with their aftermarket equipped enrichener device. It is okay to crack the throttle *and hold it there* but no turning it and then turning it off as in blipping.

I will now continue with the starting procedure as outlined in Service Bulletin M-1005.

1. Let the bike warm up for 15 to 30 seconds with enrichener full-out.
2. Ride for 5-minutes or 3-miles with enrichener full-out. My calculations indicate the speed will be 25 mph to achieve this.
3. After the 5-minute/3-mile ride push the enrichener in to the ½-way position.
4. Ride for 2-minutes or 2-miles. Doing the math indicates that the bike has to speed up to 60 mph meet this new criteria.
5. After 2-minutes-2miles riding at 60 mph, push the enrichener all the way in so that it is in the off position.
6. The CV Kehein equipped bike should now be warm and function well after this 12-minute/8-mile warm-up procedure. This includes unassisted enrichener idling at the specified preset 1000 rpm to 1050 rpm.
7. If not, pull the enrichener knob out enough to obtain a correct idle cadence.
8. Ride for an additional 2-minutes/2-miles at 60 mph.
9. Push the enrichener in to the off position. If the bike does not idle correctly, repeat the procedure in step 12. [6]

Fuel Additive to the Rescue

If the CV Kehein carburetor is really acting up in cold and damp conditions with the result that the bike will not idle, suffers power loss and rides poorly overall, H-D's Powertrain Engineering found that adding three times the normally recommended Harley-Davidson Fuel Additive (99893-86) will eliminate the problems. H-D defines cold, damp conditions as temperatures between 35^0 F and 45^0 F with a relative humidity of at least 65%. The normal amount specified on the Fuel Additive container is 1oz per 2.5 gallons of fuel. Reading carefully it is evident that the Factory does not explicitly recommend 3 oz of Fuel Additive per 2.5 gallons fuel but says that it ensures "good engine performance on cold damp days." [7] I speculate that H-D does not want to violate EPA and/or CARB regulations with this non-advice.

Front View: CV Kehein Carburetor: 1989 to 2006

Fuel is gravity fed from a gas tank locating above the carburetor and is flow-controlled by using a float operated inlet valve. The carburetor operates via a slide action variable venturi. A vacuum piston controls the venturi opening. The CV has a throttle stop screw for idle speed adjustment and there is a fuel enrichment system for starting. Idle and transfer ports provide a balanced fuel mixture during the transition period from idle to mid-range along with a slow jet. A needle extends down from the variable venturi slide and into a needle jet to provide primarily mid-range fuel requirements. Below this is the main jet whose main function is to supply high-speed fuel. With full throttle, the slide moves up fully exposing the venturi for high-speed air demand. The upward slide movement also retracts the midrange needle from its needle jet to allow more fuel to travel up from the high speed jet below. An accelerator pump assists in rapid acceleration.

If looking into the carburetor mouth, the reader will notice the venturi, a narrowing in the throat. The narrowing venturi causes air to speed up. Centered above the throat is a rounded hole 1.00" long and ⅜" wide. This is an atmospheric vent connecting to the positive side of the internal chamber underneath the vacuum piston diaphragm of the CV Kehein to assist in raising the slide in the venturi.

Next, looking on the front face of the carburetor air cleaner mount flange, the one threaded hole at the top-right and the other two threaded holes at the middle-left side and the bottom right are air cleaner mounting holes. The unthreaded hole at the left top opposite the top threaded hole is the float bowl vent.

The accelerator pump nozzle is at the right front just inside the carburetor throat. Twist the throttle and a squirt of gas will inject back into the carburetor venturi. Beside the upright (vertical) accelerator pump nozzle is the recessed (horizontal) main air jet. The horizontal slow air jet is also at the front just inside the carburetor throat beside the main air jet. It is not recessed quite as much as the main air jet. The slow jet sits near the top of the internal gasoline float bowl reservoir. It feeds gas up through a vertical channel to intersect with a horizontal channel that runs parallel to and underneath the carburetor throat and venturi. The horizontal channel begins at the slow air jet at the front of the carburetor and extends back past the interconnection with the slow gas jet channel to the transfer ports and ending with the idle port, which I will discuss further on.

The vacuum piston commonly referred to as the slide sits in its closed position inside the carburetor venturi. Below the slide is the needle jet that extends slightly into the venturi underneath the slide. It extends up from the float bowl connecting to the main bleed tube. The vacuum slide needle protrudes down into the needle jet. The main jet itself locates in the float bowl in the gasoline reservoir just below the main bleed tube. The bleed tube also intersects with the main air jet passage just below the venturi. Bottom right on the CV Kehein is the accelerator pump that is an adjunct to the float bowl. Top right rear is the throttle/idle cable bracket. Please see Volume III: *The Evolution: 1984 to 2000* for pictures of the CV Kehein from the front, rear and both sides.

Rear View: CV Kehein Carburetor: 1989 to 2006

I will describe all the hoses on the CV Kehein carburetor in more detail in the next section: *Left Side View: CV Kehein Carburetor 1989-2006.* Briefly, from the top on the rear view is the vacuum line attaching to the vacuum fitting; top right is the fuel line; right is the enrichment device cable and bottom right is the float bowl overflow vent line.

Top left, attached to the carburetor is the throttle and idle cables bracket that hold the outer cables in place. The bracket is necessary so that the inner cables can respond without the outer cables moving to the rider's opening and shutting of the throttle grip. The inner cables mount in the round spindle below that attaches to the carburetor throttle butterfly plate that locates in the center of carburetor throat, held and directed by the throttle shaft. The throttle and idle cable spindle hides the attaching end of this shaft but its center portion is visible in the center of the throttle butterfly plate affixed by two screws. Up to the middle Shovelhead years, H-D used a single throttle cable, depending solely on a return spring action to always shut the throttle off as the rider manually shuts the throttle cable. The idle cable is a safety feature that ensures the throttle will respond to rider demands and close. Previous to the spring return or the CV automatic return action, H-D utilized the *dead man's throttle.* This single throttle cable was a stiff solid wire with no return spring. The rider manually opened the throttle and had to manually close it. If the rider fell off the bike, the throttle would stay in the last position hence the descriptive name.

Late EFI Twin Cams eliminate throttle cables altogether in favor of an electronic activation system called *fly-by-wire throttle.* The rider still twists the handlebar throttle grip but it sends electric pulses to a servomotor on the side of the electronic fuel injection module and the ECM to activate the fuel injectors.

The CV Kehein throttle/idle cable spindle has a strong return spring between it and the carburetor body. A threaded idle speed adjuster screw extends through an appendage on the bottom of the throttle/idle cable bracket and butts against an outcrop near the top of the throttle plate spindle. There is a coiled spring over and around the idle screw that tensions against the plate to assist the idle screw from moving once set. If screwing it in clockwise, the idle screw will push (rotate) the spindle thus opening the throttle plate for some air delivery in combination with air/gas from the idle port and the idle transfer ports.

These ports are small and easily missed. They locate in front of the throttle plate in the top of the carburetor throat. The idle mixture screw that delivers air and fuel when the throttle plate is in the closed position controls the idle port delivery. When the throttle plate opens a bit, the air/fuel mixture will also flow through the tiny idle transfer ports at the top-rear of the inside of the carburetor venturi behind the idle port. The opening of the throttle butterfly (valve) plate exposes the idle transfer ports. If taking a CV Kehein carburetor that is off the motorcycle, the idle port and the multiple idle transfer ports are visible by turning the CV Kehein upside down and viewing the throat from the manifold mounting side.

Moving on, from the bottom of the throttle plate spindle a rod connects to an activation lever for the accelerator pump assembly. The outside of the accelerator pump assembly consists of the rubber boot under the spindle and the accelerator pump housing underneath it that is part of the larger float bowl. Inside the rubber boot and housing is a rod that extends down from the lever to a diaphragm. The accelerator pump system uses sudden throttle openings (rapid acceleration), in order to rapidly squirt fuel into the front of the carburetor venturi to provide the extra fuel necessary for smooth acceleration.

However, only the first third of complete throttle travel pushes the accelerator pump rod down, which flexes the internal diaphragm causing a rush of fuel up to the squirt nozzle in the front mouth of the carburetor throat pointing back towards the venturi . A spring returns the diaphragm back into its original position. Gas then flows from the float bowl reservoir underneath the diaphragm via pressure differentials in order to replenish for the next handful of throttle twisting. After that, the horizontal float bowl drain screw locates in the middle at the bottom of the float bowl.

Lastly the rubber flange fitted over the rear of the carburetor throat is an airtight sealing gasket that connects the carburetor to the manifold that solid mounts to the intake ports on front and rear heads. Of course, a rubber flange will not support the weight of the carburetor. The carburetor backing plate bolts to the solid front aluminum carburetor flange via three screws. This backing plate bolts to either head also providing necessary support for the carburetor.

Left-side View: CV Kehein Carburetor: 1989 to 2006

Briefly, from the top is the carburetor body cap that encloses the vacuum slide piston, spring, and jet needle. Over and beside the cap is the fuel line that travels down from the gas tank petcock to the fuel inlet fitting at the top of the CV Kehein float bowl reservoir. The protective covering over the fuel line is a safety feature since this line contains flammable gas traveling between the hot cylinder heads.

Below the top portion of the fuel line is the enrichment device cable that connects to the enrichment starter valve inside the carburetor. This is not a choke but an enrichment device that delivers fuel when opened by the cable. The enrichment (starter valve) device first meters fuel upward through a valve chamber. This occurs because the descending pistons on their intake stroke create a vacuum. The lower pressure in the venturi causes the now higher pressure in the float bowl chamber to force the gas to ascend into the lower pressure area. Then, the starter valve opens a passage into the carburetor venturi on the vacuum (rear) side of the venturi. Air also directs to the valve chamber to mix with the gas. Therefore, gas from the float bowl chamber will draw up into the carburetor venturi by the pressure differentials caused by the venturi effect and the descending pistons that create negative pressure.

Next is the vacuum line hose behind the enrichener cable. The vacuum hose attaches to the carburetor vacuum fitting which connects into the carburetor throat. The other end of the vacuum hose attaches to the VOES (Vacuum Operated Electrical Switch). The VOES sends an electrical signal to the ECM that indicates engine load according to vacuum (negative) or atmospheric (positive) pressure in the venturi. The ECM can then signal the spark plugs to fire in conjunction with piston movement location. I will fully cover this seemingly complex but simple subject in the next chapter, Chapter IX: *Synchronizing Ignition and Fuel Delivery*.

Below the enrichener cable is the buttressed end of the throttle butterfly plate shaft. To the left is the rubber carburetor to manifold flange gasket. Above, between the fuel line and the enrichener cable seated in the carburetor body is a pressed fit cap. This seals the float bowl vent channel that makes a turn at this location. Drill bits cannot bend around corners so straight bores intersect with sealing caps where necessary.

The float bowl reservoir housing attaches to the bottom of the CV carburetor. It houses the metering inlet needle and seat plus the float mechanism that contains and determines the level height of stored fuel in the reservoir. The hose at the bottom of the float bowl attaches to the float bowl reservoir overflow tube. The tube extends vertically upwards through the fuel reservoir and open ends just above the gasoline reservoir. A maladjusted or defective float mechanism can cause gas overflow. It is imperative to channel this overflow away from the hot engine components and the exhausts harmlessly, relatively speaking, onto the ground.

Tuning the CV Kehein Carburetor

Carburetion on a Harley Davidson is all about compromise. It is rarely perfect because of barometric influences and the overlapping of various fuel circuits where each has a specific primary function.

The Enrichener Circuit

The Enrichener circuit richens the AFR on startup to aid in cold starting and engine warm-up.

The Accelerator Pump

The accelerator pump squirts fuel into the carburetor throat/venturi when first twisting the throttle to also assist in starting and the transition area just off idle.

The Idle and Low Speed Circuit

The throttle closes at idle.

- Fuel metering through the slow-speed jet and a mixture screw controls idle speed when the throttle plate is barely open.

- At low speed when the throttle opens the plate a little more, additional fuel directs into the carburetor throat venturi.
- The lowered position of the vacuum piston reduces the venturi opening.
- The idle and low speed circuit controls idle and assists the transition into mid-range.
- This circuit controls 100% of idle and about 25% of right off idle low speed.
- However, the primary function of this circuit is the idle.

The Mid-Range Circuit

The mid-range circuit-slide position rises from the lower low speed location.

This movement occurs as the throttle plate opens creating a low vacuum situation that moves the piston upwards.

- There is a tapered needle attaching to the piston and it protrudes down into a tube.
- As the piston raises so does the needle out of its mating seat: the needle jet, allowing fuel to rise into the air stream atomize.
- The mid-range circuit controls steady throttle opening and lighter acceleration.

The High Speed Circuit

The high-speed circuit activates by opening the throttle plate further creating a pressure differential.

- This raises the piston slide fully upwards opening up the venturi to its full size.
- Vacuum controls the slide that lifts the needle all the way up with wide-open throttle during hard acceleration.
- The high-speed circuit controls the amount of gas passing by via a main jet that the tapered needle slides up-and-down.
- The needle jet opens to its maximum allowing in enough fuel to meet engine demands.
- In this situation, of wide-open throttle during hard acceleration the main jet is the primary controller of fuel delivery.

However, the needle will also control fuel for everything in-between idle and full tilt boogie.

It will start to fuel right off idle with light throttle.

- As the throttle opens, air velocity increases under the slide and fuel will draw up from around the needle, even before the slide begins to lift.

Locating the Jets, Float Vent, and the Accelerating Pump Nozzle

If removing the air cleaner, the float-bowl vent, accelerating pump nozzle, the slow air jet, and the main air jet are visible at the front of the carburetor throat.

1. The unthreaded float bowl vent hole locates on the front left top of the carburetor air cleaner mount flange.
2. The accelerator pump nozzle is at the right front just inside the carburetor throat. Twist the throttle and a squirt of gas will inject back into the carburetor venturi.
3. Beside the upright (vertical) accelerator pump nozzle is the recessed (horizontal) main air jet. The horizontal slow air jet is also at the front just inside the carburetor throat beside the main air jet. It is not recessed quite as much as the main air jet.
4. The idle mixture screw locates at the rear of the carburetor underneath the carburetor throat.
5. The idle port is directly above the idle mixture screw at the bottom of the carburetor throat just behind the throttle butterfly plate.
6. The slow jet sits near the top of the gasoline float bowl reservoir. The slow jet feeds gas up to through a vertical channel to intersect with a horizontal channel that runs parallel to and underneath the carburetor throat and venturi. The horizontal channel begins at the slow air jet at the front of the carburetor and extends back past the interconnection with the slow gas jet channel to the transfer ports and ending with the idle port.
7. The closed throttle plate blocks the transfer ports. As the throttle plate opens, the transfer ports expose and more fuel directs into the carburetor throat on the engine side of the venturi.
8. The main bleed tube extends up from the float bowl connecting to the needle jet that extends slightly into the venturi. The vacuum slide needle extends down into the needle jet. The main jet itself locates in the float bowl in the gasoline reservoir just below the main bleed tube. The bleed tube also intersects with the main air jet passage just below the venturi.

Troubleshooting the CV Kehein

Consult your various manuals for troubleshooting charts, tips, and a better understanding of this carburetor that has served the late Evolution, Sportster, and the Twin Cam well.

Damaged CV Kehein Float Needles 1993 and 1994

On January 28, 1994, it became apparent that *some* fuel (float) valve needles, part number 27886-78A in Parts and Accessories, Carburetor Repair Kit number 27006-92T for CV Kehein carburetors were damaged. The needle clip groove on one side was (is) damaged. It is crushed down. Do not repair these by inserting a thin object and bending back in place as a piece may break off while in service. The appropriate repair is to discard the damaged float needle and use a new undamaged one. The packages have one of two dates on them; September 1993 (9/93) or November 1993 (11/93). The customer concern code is 9900 and the condition code is 9100. As always, H-D attempts to recover and destroy faulty parts but some invariably find their way into unscrupulous hands. There may still be some floating around for sale in swap meets or on the Internet, which is why I mention this for Twin Cam owners.

Common Problems and Solutions

The reader will quickly observe many common problems and solutions. Gas cap venting, float levels, dirty air filters, sediment in the gas tank, and carburetor air leaks top the list. In short, troubleshooting problems is many times necessary because of inadequate maintenance.

The (Starter) Enrichener Valve

The Enrichener Valve (27583-88) causes many problems as it wears. I make special mention of this valve because:

1. It has two names that confuse rider's working on their own bikes and novice mechanics alike. The H-D part book, 99450-94A, I am currently using calls this device a starter valve while another H-D manual, 99483-99 calls the same device an enrichener valve.
2. Secondly, at least in my neck of the woods, H-D technicians seem to miss faulty enrichener/starter valves all the time and perform other adjustments and fixes that do not work. I cannot tell the reader how many bikes come to my shop after dealer repairs to solve the original problem of a faulty valve. I also have to order starter valve inventory from about 100 miles away because my local dealers never stock the starter valves either because they do not realize how problematic they can be.
3. Thirdly, this enrichener (starter) valve causes many tricky symptoms as it wears or becomes contaminated with dirt. The bike may run richer with a low air-fuel-ratio:
    - The engine will run rough.
    - The bike may have poor acceleration.
    - The idle may vary, going up and down, seemingly at will. Adjusting the idle will not fully cure the situation and may mask symptoms.

Increasing air intake may seem to temporarily solve the symptom and thus seemingly the problem of a faulty valve.

I guess riders and some mechanics do not totally understand how an enrichment device works relative to a choke plate. The choke is easy because the observer can watch it open and close in the carburetor throat. A choke plate stops the amount of air entering the carburetor throat changing (richening) the AFR. An internal out-of-sight enrichment valve/starter valve located on the left side, rear of the CV just under the carburetor top allows extra fuel into the system to enrichen the AFR. Actually, as the enrichener valve cable is pulled out converging fuel and air passages open. Vacuum causes fuel to rise through the enrichener jet located in the float bowl at the bottom of the carburetor. The fuel rises upward through a passage to the enrichener/starter valve chamber where it mixes with air.

However, I do not understand mechanics looking for a complicated fix when symptoms of black smoke coming out of the pipes and darkened spark plug electrodes combined with rough idling are right in front of their faces.

One last thing, the reader might have noticed an -88 suffix on the starter/enrichment valve part number indicating first use in 1988. Of course, the Evolution Big Twin began first use in MY 1989 and full use in 1990. The Sportster began using the CV Kehein carburetor in 1988. There are differences between the CV carburetors serving engines from 883cc to 1200cc to 1340cc to 1450cc but they all use the same enrichment starter valve, 27583-88 from 1988 to the last year of CV Kehein use on a Harley-Davidson in 2006.

In the following troubleshooting tips, I try to put the causes and remedies in order of ease and least expense working progressively up to difficult and most cost.

Poor Gas Mileage

1. Riding the bike at high speed all the time. The only way to improve fuel economy in this case is to slow down.

2. Check the gas cap vent. If plugged, remove dirt with a wire or compressed air or else replace the gas cap. All single gas tank gas caps vent. The right side gas cap vents on dual fuel tank caps.
3. Inspect the air filter. If dirty, clean. Replace if necessary.
4. Idling improperly adjusted. Adjust to specifications.
5. Overuse of the enrichment device (starter valve) putting excess gas into the engine.
6. Inspect for too much gas exiting the accelerating pump nozzle. If so, replace the nozzle.
7. Inspect to see if the enrichener valve is leaking. If so, adjust or replace if necessary.
8. Inspect to see if the enrichener valve is not seated. Adjust or clean if necessary.
9. Check float bowl vent for obstruction or partial clogging. If obstructed, clean.
10. Inspect float level; if too high adjust the float level. The measurement between the carburetor flange face to the outside of the perimeter of the float must be between .725" and .730". There are different methodologies to set the float level. Consult your manual for year and model.
11. Inspect needle and needle jet for damage. Replace if necessary. Do not repair these parts if damaged. I always replace the pair since if there is damage to one, there may very well be damage to the mating part.
12. Inspect carburetor jets and tighten if loose.
13. Inspect bleed tubes, passages and air jets for clogging. Clean if necessary.
14. Inspect the vacuum piston assembly. Please see the following two sections, *Vacuum Piston Fails to Close* and *Vacuum Piston Fails to Raise.*

Vacuum Piston Fails to Close

1. Inspect vacuum spring for binding. Correct; replace if necessary.
2. Ensure piston is not binding. If so, it is very important to clean the piston and it's mating slide of any burrs or imperfections. Replace piston if necessary.
3. Inspect piston diaphragm ring for dirt or damage. Clean if possible; replace if necessary

Vacuum Piston Fails to Raise

1. Check if enrichener valve is open. Close; adjustment may be required.
2. Check if enrichener valve is not seating correctly. Adjust; replace if necessary.
3. Check if enrichener valve is leaking. Adjust, blow out with compressed air or replace.
4. Inspect diaphragm cap at bottom of the float bowl. If loose, tighten.
5. Inspect diaphragm cap for fuel leakage. Tighten; if this does not correct leakage, replace the cap.
6. Inspect diaphragm for pinching at the lip groove. If undamaged position diaphragm correctly or replace. I always replace it for the money it costs.
7. Inspect diaphragm for tearing, cut(s), or any type of damage. Replace, if not perfect.
8. Inspect piston atmosphere vent for obstruction or clogging. Clean until vent is clear of any obstruction.

9. Inspect vacuum spring for binding. Correct; replace if necessary.
10. Ensure piston is not binding. If so, it is very important to clean the piston and it's mating slide of any burrs or imperfections. Replace piston if necessary. Insect piston vacuum passage at the same time; see item 11.
11. Inspect piston vacuum passage for obstruction or clogging. Clean until passage clear.

Rough Idling Quality

1. Check to see if the idling adjustment (idle speed) is correct. If not set idle
2. speed adjustment.
3. Check the gas cap vent. If plugged, remove dirt with a wire or compressed air or else replace the gas cap.
4. Inspect various sealing components for an air leak, which may include a worn throttle plate shaft through the carburetor body; worn gasket/seal between the carburetor and the manifold; loose mounting nuts or the most likely culprit leaky manifold rubber sealing. Replace worn parts, retighten loose fasteners, and *always* use new rubber seals.
5. Check if enrichener valve is open. Close, adjustment may be required.
6. Check if enrichener valve is not seating correctly. Adjust; replace if necessary.
7. Check if enrichener valve is leaking. Adjust, blow out with compressed air or replace.
8. Inspect the accelerating pump for leakage. Repair or replace.
9. Check if low speed jet is loose. If so, tighten the jet.
10. Determine if low speed jet or low speed system is blocked or partially clogged. If so clean until unobstructed.

Hard Starting

1. Ensure there is fuel in the tank and petcock is turned to the ON position.
2. Use the enrichener device. I know this is obvious but not using it may cause hard starting.
3. Inspect fuel supply. Correct if impeded in any way (e.g. fuel line kinked, rubber deteriorated, fuel reaches and enters the carburetor).
4. Inspect carburetor cleanliness. Clean if dirty.
5. Inspect float level if there is gas overflow; if too high adjust the float level as described above and/or clean to remove sediment.
6. Inspect various sealing components for an air leak, which may include a worn throttle plate shaft through the carburetor body; worn gasket/seal between the carburetor and the manifold; loose mounting nuts or the most likely culprit leaky manifold rubber sealing. Replace worn parts, retighten loose fasteners, and always use new rubber seals.
7. Inspect and ensure the enrichener system is operating correctly. Clean, adjust, repair or replace as necessary.
8. Inspect slow jet and passages for obstruction or partial clogging. Clean as necessary for unimpeded flow.

Poor Gas/Air Mixture

1. Inspect carburetor cleanliness. Clean if dirty.
2. Inspect fuel line for internal dirt, blockage and kinking. Clean or replace. I always replace the line if problematic.
3. Inspect various sealing components for an air leak, which may include a worn throttle plate shaft through the carburetor body; loose mounting nuts or the most likely culprit leaky manifold rubber sealing. Replace worn parts, retighten loose fasteners, and always use new rubber seals.

Gas Overflow

1. Check for loose float chamber screws. If loose, tighten.
2. Check the gas cap vent. If plugged, thus allowing the fuel tank to pressurize forcing fuel down into the float bowl, remove dirt with a wire or compressed air or else replace the gas cap.
3. Check for dirt in the float inlet valve (needle) seat. Blow out with compressed air.
4. Inspect for a worn inlet valve (float needle). Replace if necessary.
5. Inspect float level; if too high adjust the float level as described above.
6. Inspect float assembly; if damaged or leaking fuel into the float; replace and readjust float level.
7. Check float O-ring gasket for wear. If so, replace with a new O-ring gasket. I replace the gasket and seals every time I work on a carburetor.
8. Inspect float halves for misalignment. If askew, align float halves and readjust the float

Poor Riding Performance

1. Check the gas cap vent. If plugged, remove dirt with a wire or compressed air or else replace the gas cap.
2. Check air filter. If dirty, wash or replace.
3. Ensure the accelerator pump is functioning. Repair or replace as necessary.
4. Inspect fuel supply tract for restrictions. Clean, repair or replace parts as necessary.
5. Inspect internal carburetor for cleanliness. If dirty, clean.
6. Inspect float bowl vent and overflow for obstruction. Clear obstruction.
7. Check spark plugs to see if there is an intake air leak. If plugs are blistery-white, find air leak. Replace seals.
8. Check idle for proper adjustment. If idle not within specifications, adjust to specifications.
9. Inspect and ensure the enrichener system is operating correctly. Look for leakage and if the enrichener valve is seating properly. Clean, adjust, repair or replace as necessary.
10. Inspect for loose fuel and air jets. Tighten or replace as necessary.
11. Inspect fuel and air jets and related passages for obstructions or partial clogging. Clean, repair, or replace as necessary.
12. Inspect vacuum piston needle and needle jet for wear or damage. Replace if necessary.
13. Inspect for a vacuum piston malfunction. Please see the above two sections, *Vacuum Piston Fails to Close* and *Vacuum Piston Fails to Raise.*

Poor Acceleration

Check that the accelerating pump is squirting fuel into the venturi. If not, clean the system until unclogged; replace components as required.

1. Check the gas cap vent. If plugged, remove dirt with a wire or compressed air or else replace the gas cap.
2. Inspect fuel supply tract for restrictions. Clean, repair or replace parts as necessary.
3. Inspect throttle and idle cables for misalignment. Adjust if necessary.
4. Inspect various sealing components for an air leak, which may include a worn throttle plate shaft through the carburetor body, loose mounting nuts or the most likely culprit leaky manifold rubber sealing. Replace worn parts, retighten loose fasteners, and always use new rubber seals.
5. Inspect float bowl vent and overflow for obstruction. Clear obstruction.
6. Inspect and ensure the enrichener system is operating correctly. Look for leakage and if the enrichener valve is seating properly. Clean, adjust, repair or replace as necessary.
7. Inspect float level. Adjust if necessary.
8. Inspect fuel and air jets and related passages for obstructions or partial clogging. Clean, repair, or replace as necessary.
9. Inspect vacuum piston needle and needle jet for wear or damage. Replace if necessary.
10. Inspect for a vacuum piston malfunction. Please see the above two sections, *Vacuum Piston Fails to Close* and *Vacuum Piston Fails to Raise*.

High Speed Performance Problems

1. Check the gas cap vent. If plugged, remove dirt with a wire or compressed air or else replace the gas cap. Inspect fuel supply tract for restrictions. Clean, repair or replace parts as necessary.
2. Check that the accelerating pump is squirting fuel into the venturi. If not, clean the system until unclogged; replace components as required.
3. Inspect the air filter. If dirty, clean. Replace if necessary.
4. Inspect various sealing components for an air leak, which may include a worn throttle plate shaft through the carburetor body, loose mounting nuts or the most likely culprit leaky manifold rubber sealing. Replace worn parts, retighten loose fasteners, and always use new rubber seals.
5. Inspect and ensure the enrichener system is operating correctly. Look for leakage and if the enrichener valve is seating properly. Clean, adjust, repair or replace as necessary.
6. Inspect external aftermarket fuel filter if equipped. Clean sediment and/or replace filter.
7. Inspect fuel petcock internal fuel strainer (filter). Remove sediment. Flush fuel tank(s) if necessary or the problem will certainly reoccur.
8. Check float level; a low adjustment may cause performance problem. Adjust if necessary according to instructions above (.63 to .67"/16mm to 17mm). There are different methodologies to set the float level. Consult your manual for year and model.
9. Inspect fuel and air jets and related passages for obstructions or partial clogging. Clean, repair, or replace as necessary.

10. Inspect vacuum piston needle and needle jet for wear or damage. Replace if necessary.
11. Inspect for a vacuum piston malfunction. Please see the above two sections, *Vacuum Piston Fails to Close* and *Vacuum Piston Fails to Raise.*

As I say at the beginning of every troubleshooting piece, this section on *Troubleshooting the CV Kehein* is no different; most problems occur because of rider neglect and inadequate daily or weekly maintenance.

	FLT/FLHT		**FXST/ FLST**		**FXD**		**FXR**	
	Slow jet[1]	Main Jet	Slow	Main	Slow	Main	Slow	Main
1990	45 2	185 [2]	45	185	NA [3]	NA	45	185
1990 CARB [4]	42	165	42	165	NA	NA	42	165
1991	45	185	45	185	45	185	45	185
1991 CARB	42	165	42	165	42	165	42	165
1992	40	175	40	165	40	175	40	175
1992 CARB	40	160	40	160	40	160	40	160
1993	40	175	42	175	42	175	40	165
1993 CARB	40	160	42	160	42	160	40	160
1993 HDI [5]	40	165	40	165	40	165	40	165
1994	42	165	42	175	42	165	42	165
1994 CARB	42	165	42	165	42	165	42	165
1994 HDI	40	165	42	165	40	165	40	165
1995	42	165	42	165	42	165	NA	NA
1995 CARB	42	165	42	165	42	165	NA	NA
1995 HDI	42	180	42	180	42	180	NA	NA
1995 Swiss	40	165	40	165	40	165	NA	NA
1996	42	170	42	170	42	170	NA	NA
1996 CARB	42	175	42	175	42	175	NA	NA
1996 HDI	42	180	42	180	42	180	NA	NA
1996 Swiss	42	180	42	180	42	180	NA	NA
1997	42	170	42	170	42	170	NA	NA
1997 CARB	42	175	42	175	42	175	NA	NA
1997 HDI	42	180	42	180	42	180	NA	NA
1997 Swiss	42	180	42	180	42	180	NA	NA
1998	42	175	42	175	42	175	NA	NA
1998 CARB	42	175	42	175	42	175	NA	NA
1998 HDI	42	180	42	180	42	180	NA	NA
1999	42	185	42	170	45	190	NA	NA

1999 CARB	42	185	42	175	42	180	NA	NA
HDI	42	195	42	180	42	180	NA	NA
2000 [6]	45	190	42	170	45	190	NA	NA
2000 CARB	45	185	42	175	42	180	NA	NA
HDI	45	195	42	180	45	190	NA	NA
2001	45	190	42	170	45	190	NA	NA
2001 CARB	45	185	42	175	42	180	NA	NA
HDI	45	195	42	180	45	190	NA	NA
2002	45	190	45	190	45	190	NA	NA
2002 CARB	45	185	45	190	45	190	NA	NA
HDI	45	195	45	190	45	190	NA	NA
2003	45	190	45	190	45	190	NA	NA
2003 CARB	45	185	45	190	45	190	NA	NA
HDI	45	195	45	190	45	190	NA	NA
2004	45	190	45	190	45	190	NA	NA
2004 CARB	45	185	45	190	45	190	NA	NA
HDI	45	195	45	190	45	190	NA	NA
2005	45	190	45	190	45	190	NA	NA
2005 CARB	45	185	45	190	45	190	NA	NA
HDI	45	195	45	190	45	190	NA	NA
2006	45	190	45	190	EFI [7]	EFI	NA	NA
2006 CARB	45	185	45	190	EFI	EFI	NA	NA
HDI	45	195	45	190	EFI	EFI	NA	NA

Please confirm jet sizing for your year and model in service manual. Later manuals for earlier year part numbers may supersede earlier sizing because of changing emissions controls, upgrades, and/or service bulletins advising changes to original fitment. In other words I have made every effort to be accurate but this chart should be used as a general guide.

If the reader compares USA jetting (49-State + CARB) chronologically by year, it is generally evident that emissions controls get ever more restrictive as the years roll by causing engines to run leaner with more air relative to fuel in order to burn the highest percentage of emissions possible. In 1994, 49-State and CARB begin to almost always use the same jet sizing since jetting becomes as lean as possible for the bike to still function satisfactorily. As the year 2000 approaches, jetting richens a little as it appears that carburetor jetting became too lean for the oppressed 45° air-cooled, 2-cylinder V-Twin.

[1] The slow jet is also known as a pilot jet.

[2] For simplicity, jet sizing identification leaves out the decimal point. A 45 slow or pilot jet is more correctly and accurately referred to as .045mm. A 185 main jet is more correctly and accurately referred to as 1.85mm. The jet sizing is in metric measurement because they are Japanese carburetors and Japan like most of the world uses metric (1mm = 1 millimeter = 0.03937 inch).

[3] NA = Not Applicable. The Dyna series motorcycles did not begin production until 1991. Evolution FXR's ceased production after 1994 except for the CVO Screamin' Eagle FXR^2 and FXR^3 in 1999 and the FXR^4 in 2000.

[4] CARB = California Air Resources Board. California carburetor slow and main jet sizing required to meet CARB emissions dictates. Compare the much smaller jetting for California models servicing the same size engine as in use in the rest of the USA. CARB emissions controls are much stricter than those of the 49-State EPA (Environmental Protection Agency). The smaller jetting allows less gasoline in to mix with a higher percentage of air creating a lean condition that robs potential power output. California CARB engines run hotter than the 49-State ones.

[5] HDI = Harley-Davidson International. HDI motorcycles are for export around the world. Jetting is generally leaner than 49-State EPA controls. However, different countries and unions will have different requirements where Harley-Davidson may rejet to other specifications than listed here. Canada, for example uses 49-State jetting whereas the European Union will have stricter TÜV controls. TÜV is the European equivalent of the EPA.

[6] 2000 FXR[4] is the only Evolution powered motorcycle in this year. All other models are powered by the Twin Cam engine and transmission.

[7] All Dyna models (FXDLI, FXDWGI, FXD35, FXDI, FXDCI, and FXDBI) in 2006 are equipped with Delphi electronic fuel injection.

CV Kehein Jet Sizing

The jet sizing listing is accurate for a base start. Always diagnose a lean or rich condition first. Then examine the *actual* jet or jets in the carburetor to determine what will be the next step larger (richer) or smaller (leaner) that is necessary for correct tuning. The novice tuner should replace one jet sizing at a time. Experienced tuners may go more than one size at a time if necessary. Beware a Sportster CV Kehein carburetor on a Big Twin and vice versa since the stock jetting may be too rich or too lean if a specific carburetor's intended use is mixed up. This will not be a problem on a new or close to new stock Harley-Davidson. However as carburetors wear or ground-up engine builds occur, swap meet or similar purchase used carburetors may mix inappropriately. Some models received the CV Kehein carburetor in MY 1989. Use 1990 jetting specifications for these bikes.

CV Kehein 1989 to 2006 Jet Part Numbers

Main Jet	OEM # [1]	Slow Jet	OEM #
1.60mm	27152-89	.040mm	29281-92
1.65mm	27116-88	.042mm	27171-89
1.70mm	27115-88	.045mm	27100-88 27170-89
1.75mm	27090-89	.048mm	27165-90
1.85mm	27185-90		
1.90mm	27243-95		
1.95mm	27275-96Y		

There are smaller and larger jets available from Kehein or the aftermarket in .05mm increments for main jets and either .001mm but more usually .002mm for slow/pilot jets.

[1] OEM = Original Parts Manufacturer part number

Jet sizing identification leaves out the decimal point in most literature but this is not correct. The size of the jet measures the diameter size of the hole or orifice that the fuel flows through.

A 45 slow or pilot jet is more correctly and accurately referred to as .045mm. Therefore the jet orifice has a diameter of .045 millimeters. A 185 main jet is more correctly and accurately referred to as 1.85mm. Therefore the jet orifice has a diameter of 1.85 millimeters. The reader can measure the orifice size by using metric drill bits, which is a handy way of avoiding buying more expensive measuring tools. The mechanic can also drill out a smaller jet orifice to a bigger one but of course cannot make a larger jet smaller.

CV Kehein Carburetors: 1989 to 2006

Year	Dyna FXR Softail [1]	FLT	California Dyna, FXR Softail [1]	California FLT	HDI Dyna, FXR Softail [1]	HDI [2] FLT
1989	27038-90	27039-90	27035-90	27026-90	27025-90	27029-90
1990	27038-90A	27039-90A	27035-90A	27026-90	27025-90A	27029-90A
1991	27038-90A	27039-90A	27035-90A	27026-90A	27025-90A	27029-90A
1992	27038-92	27039-92	27035-92	27026-92	27025-90A	27029-90A
1993	27026-93	27207-93	27035-92A	27026-92A	27025-90A	27039-92
1994	27206-93	27207-93	27035-92A	27026-92A	27025-90A	27039-92
1995	27026-93A	27207-93A	27035-95	27026-95	27088-95	27083-95
1996	27492-96	27493-96	27504-96	27505-96	27088-95	27083-95
1997	27492-96	27493-96	27504-96	27505-96	27088-95	27083-95
1998	27492-96	27493-98	27504-96	27505-98	27088-95	27083-98
1999	27492-96 27413-99	27412-99	27421-99 27414-99	27415-99	27088-99 47421-99	27422-99
2000	27492-96 27421-99A	27412-99A	27421-99A 27414-99A	27415-99A	27421-99	27422-99A
2001	27421-99A	27412-99A	27414-99A	27415-99A	27421-99A	27422-99A
2002	27421-99B	27412-99B	27414-99B	27415-99B	27421-99B	27422-99B
2003	27421-99C	27412-99C	27414-99C	27414-99C 27415-99C	27421-99C	27422-99C
2004	27421-99C	27412-99C	27414-99C	27427-04	27421-99C	27422-99C
2005	27421-99C	27412-99D	27414-99C	27427-04	27421-99C	27422-99C
2006	27421-99D	27412-99D	27414-99D	27427-04	27421-99D	27422-99C

Please confirm CV Kehein carburetor for your year and model in service manual. Later manuals for earlier year part numbers may supersede earlier sizing because of changing emissions controls, upgrades, and/or service bulletins advising changes to original fitment. In other words this chart has made every effort to be accurate but should be used as a general guide.

The Kehein carburetor and the CV Kehein are very different carburetors. The CV Kehein began appearing on some MY 1989 models whereas others did not receive them until 1990 full production. I put part numbers in for 1989 although some models continued use of the Kehein for the whole year's production. The Kehein carburetor saw last use in 1989. In 1999, the only Evolution models available are the Softail models and the FXR CVO Screamin' Eagle FXR[2] and FXR[3]. Year 2000 only sees one Evolution the CVO Screamin' Eagle FXR[4]. Many times a different part numbers indicate a minor change such as a cosmetic one or a jet change to reflect stricter emissions controls, which is the primary difference between California only carburetors and 49 State ones. When a suffix letter is attached to the end of the part number such as an A for the first change, and B for a second change and so on, this will usually indicate an upgrade to carburetor reliability or performance issue.

[1] FXR models began in 1982 and ended in 1994 except for the CVO Screamin' Eagle FXR's in 1999 (FXR[2], FXR[3]) and 2000 (FXR[4]). For the analytical thinkers, there was no Screamin' Eagle CVO FXR[1]. The FXD Dyna series did not begin until 1991 and continue to present day. Softail and FLT touring model production span all years of mainstream Evolution production, 1984 to 1999.

[2] HDI is the acronym for Harley-Davidson International. HDI motorcycles and component parts are those sold everywhere else but the USA. Different countries have specific regulations such as varying emissions controls that may differ from those in America. Harley-Davidson has always accommodated (reasonable) specific requests for production runs for particular city or country orders especially for police or military. It was not until 1988 that the Motor Company began making specific bikes for California to comply with CARB (California Air Resources Board) regulations. These changes or differences from 49-State models revolve around emissions compliance with the addition of catalytic converters and evaporative emissions controls. Camshaft configurations (duration and overlap), mufflers and fuel delivery and ignition fuel/spark maps will also usually be different. HDI models may be specific to certain countries like Switzerland or Japan so there may be different part numbers in any one year for different HDI countries.

Spark Plug Color Tuning the CV Kehein

This section is most applicable to carbureted motorcycles. However, spark plug tuning can also be done with EFI if using an ECM modifier like Power Commander or a host of other fuel modifiers on the market. I discuss these at length in Volume II: *Performancing the Twin Cam* in Chapter IX: *Fuel Delivery*, pages 460 to 472.

A common complaint is an off-idle *pop* or backfiring out through the carburetor at slow engine speeds.

I immediately advise the owner to assure that there is not a manifold air leak, as this will also cause this annoying rider problem. It is also dangerous for engine components that are exposed to the resultant searing heat.

1. If not a manifold leak, this is usually an excessively lean idle mixture. This easily corrects by up jetting.
2. I like to do the jetting in two stages; first, perform the idle and low-speed jetting and then proceed to the high speed or main jetting.

Ignition Timing must be Correct

I will be describing spark plug readings, so it is imperative that with this methodology the ignition timing is correct. In addition, the ignition system must be functional up to manual specifications.

- A weak yellow or non-existent spark will drastically alter spark plug readings.
- Sparking across the plug electrode should be crisp and either white or blue in color.

I am going to use the CV Kehein for my example. Adjustments for the S&S Super E, the HSR Mikuni Smoothbore and other carburetors in popular use will be different. Consult the manual for the particular carburetor in service. However, I will be discussing these carburetors in great detail in Volume II: *Performancing the Twin Cam* in the section titled, *Tuning the S&S Super E and G Carburetor* and in section, *Tuning the Mikuni Smoothbore Carburetor.*

Tuning Sequence

1. First, correct the idle and low speed jetting.
2. Then work on the high speed or main jetting.

Spark Plugs

Before starting, have at least three new sets of plugs gapped and ready to use. I favor Champion plugs for both plug readings and for use in Harley Davidson. However, mechanics have differing luck with different brand spark plugs. One thing is for sure; Champion is less expensive than H-D spark plugs. I also believe Champion has private-branded spark plugs for the Factory over the years.

1. TC88/96 1999-to-present and Evolution Sportster 1986-to-present use Champion RA8HC.
2. Evolution Big Twin from 1984 to 2000 uses Champion RN12YC.
3. Set plug gap between .038" and .043".

Idle Mixture

Adjust the idle mixture while idling. Closing the idle mixture screw slowly should cause the idle to become rough.

Slowly turn the screw out until the engine again idles smoothly.

1. Add ⅛ to ¼-turn more.
2. If closing the screw makes no difference in idle speed or smoothness, replace the pilot jet with one size under.

Most USA Big Twins use pilot jet #42 as the stock one until the circa-2000 model year and then most use #45 until 2006. Consult the workshop manual for year and model. This presents an irritation because H-D applies their part numbers to these and other jets. I made up a chart for ease of reference titled CV Kehein Jet Sizing above in this chapter. I usually cross-reference them on the Internet or with an aftermarket parts manual.

In some cases, depending on the bike set-up and higher altitude, #45 may be too large. An aftermarket #44 pilot jet works very well under most conditions.

If finding it necessary to turn the screw out more than three turns, increase the pilot jet size to the next larger size.

Low Speed Circuit Plug Tuning

After setting the idle speed and idle mixture correctly, change to a fresh set of spark plugs. Following the spark plug installation:

1. Ride the bike at part throttle, gently accelerating but keeping below ½-throttle.
2. The goal for this stage of tuning is to stay within the low speed circuit as much as possible.
3. After a mile or more, pull in the clutch, press the kill button and coast to a stop on the side of the road.
4. Using the glove and plug wrench from your back pocket, remove the *hot* sparkplugs.
5. Examine the insulator from the tip down as far as is visible.
6. The correct colors are white without blistering, off white or off-white with a very slight tan tinge.
    - Blistering indicates a too-lean AFR condition and is dangerous
    - A tan, brown, chocolate brown or black fluffy color indicates a progressively rich to very rich AFR condition that creates excess fuel consumption and a potential power loss.
    - Flat black fluffy residue is always a gas-fouling situation whereas; shiny scaly black residue is certainly combustion chamber oil blowby fouling. Either situation can easily prevent the bike from starting or running.

Front Cylinder Spark Plug Color is the Tuning Baseline

It is normal for the rear cylinder spark plug to read slightly richer than the front. The reason for the difference is inherent in the design of the 45°-inline cylinders and the intake manifold design.

The correct procedure is to change jetting up or down basing on the front cylinder spark plug reading.

1. Up jetting corrects a lean condition, whereas down jetting in size corrects a rich AFR condition.

Before changing (slow speed) pilot jets try to richen or lean the mixture by turning the mixture screw in to lean a rich AFR condition or turn it out to richen a lean AFR scenario. Once the plug reading is acceptable, proceed to the main jetting.

High Speed Plug Tuning

Main jetting by spark plug reading requires a highway since safe acceleration at wide-open throttle through the gears up to and including fourth gear is necessary. Fifth gear is theoretically better but wide-open throttle will take this diagnostic testing into illegal and sometimes dangerous speeds.

1. The procedure is simple; change to a fresh set of plugs, start the bike and immediately accelerate at wide-open throttle through the gears including fourth gear.
2. Idling or using part throttle will bastardize the plug readings and possibly negate the test.
3. After accelerating through fourth gear, pull in the clutch; push the kill switch and coast to a stop.
4. Remove the spark plugs. If the rider forgot to put on a glove for the first test, forgetfulness surely will not be a problem this time around.

5. Examine as before and follow the same procedure with the main jet.
6. If the plugs are reading very white or white with blistering, correct this lean to very lean condition by increasing one size on the main jet.
    - If the plugs are reading a tan, brown, chocolate brown or black and fluffy, correct this rich condition by decreasing at least one size on the main jet depending on how dark the plug reads.
    - Repeat this procedure until the plug readings are correct.

Fine Tuning

As the above procedure closes in on the correct main jet, it is time to fine tune with the needle.

1. Raising the needle clip will lower the needle thus leaning out the AFR mixture.
2. Lowering the clip will raise the needle thus enriching the AFR mixture.
3. If the carburetor does not incorporate a clip on the needle for adjustment, thin washers, if necessary can accomplish the fine-tuning.
4. After ensuring the spark plugs read correctly, the jetting is as good as good can get and the carburetor will produce maximum power and the most mileage relative to power for the engine and carburetor configuration.

Managing the engine

Harley-Davidson is achieving tremendous strides in managing all aspects of engine running. It must balance the goals of producing power, efficiency, fuel economy, and less noxious emissions. Unfortunately, fewer emissions will sometimes conflict with maximum power considerations.

Engine Management Systems

The V-Fire III computerized ignition system saw first use in 1983. This ECM fuel supervision and ignition system forms the basis of the present day engine-management-systems a full twelve years before first use of EFI on Big Twin touring bikes in 1995. The present day electronic control module co-ordinates engine management in a far more sophisticated fashion but it all builds on V-Fire III goals.

Carburetion Integrated Ignition

There are four main sensors that feed information to the ECM that contains the spark map matrix on timing when the spark plug should ignite on the carbureted models. Using this system with a carburetor is a first for Harley. The sensors vary whether for carburetion or fuel injection.

The carburetor sensors with their short form acronyms are:

1. CKP-Crank or flywheel speed and position (32497-99).
2. CMP-Camshaft speed and position (32496-99).
3. MAP-Manifold Air Pressure (32316-99).
4. BAS-Bank Angle (32495-98)

Five other components are required for the carbureted Twin Cam ignition system:

1. Battery.
2. Ignition coil (single fire).
3. Electronic Control Module (ECM)
4. RFI (radio frequency interference) protected spark plug wires.
5. RFI spark plugs.

All electronic ignitions require RFI plugs and wires. Otherwise, radio frequency transmissions can interfere with and confuse the electrical pulses in an electronic ignition, sometimes shutting down the ignition and thus the motorcycle.

After the sensor information computes, the ECM consults its spark map matrix to signal the ignition coil (31639-99) to spark the 12mm 6R12 plugs (32317-86A). This ignites and burns the incoming fuel charge to produce the best efficiency in terms of power. Emissions controls sometimes compromise this.

Of course, the single fire ignition requires a different coil or, put more precisely, two coils in one and better quality spark plug wires (31992-99). Each separate coil services its own cylinder sparking. As I said earlier, when one cylinder-piston is on its upwards compression stroke, the other cylinder piston is on its upwards exhaust stroke. This is why a single coil must be dual fire to ensure that the spark occurs on opposing cylinder compression strokes. This means it must also fire on each cylinder's exhaust strokes in order to accomplish firing on both compression strokes. Twin Cam EFI also utilizes a single fire ignition system.

Camshaft Position Sensor

The Camshaft Position Sensor (32496-99) also known by its acronym CMP locates in front of the timing cover and incorporates a Hall effect sensor. The Hall effect ignition pickup unit is located inside the timing cover on the primary 34-tooth rear-cam-drive-gear that attaches to the outboard rear-cam-journal that extends through the cam-support-plate.

There is a semi-circular ridge called a rotor on the outer side of this gear. This ridge rotates with the camshaft. The portion of the circle without a rotor (ridge) break is known as a window. The ridge location, beginning and end gives engine timing information as all interacting engine parts time to each other. As the ridge on the cam gear turns with the rotating rear cam, it breaks the magnetic field of the Hall effect Sensor. An electrical pulse is generated by the power source of +5 volts back to the ECM. The pulse instructs the ECM regarding engine phase, which is the technical explanation. In plain English, if the ECM knows the cam position, it will also know valve(s) position(s) relative to their seat(s) and piston locations, which will also indicate crankshaft degrees rotation of the flywheels. Every moving engine component times to each other.

1. The Camshaft Position Sensor (CMP) is no longer used after circa 2001 in part because of Twin Cam timing chest parts breakdown problems.
2. The Crankshaft Position Sensor (CKP) takes on the added responsibilities after the CMP discontinuance it was pretty much duplicating anyway.

Crankshaft Position Sensor

The Crankshaft Position Sensor (32497-99) known by its acronym as the CKP Sensor locates in the front of the left crankcase half above the alternator plug.

The CKP measures and also sends information to the ECM regarding internal engine speed. The methodology of deriving this information is from reading the 30-indent cut teeth in the left side flywheel as it rotates with the crank. Again, every moving part of consequence inside a Harley engine is timed to each other. Once knowing the flywheel position, the ECM will also know cam position, valve opening and closing positions, as well as piston location. There are two missing teeth cuts in the flywheel rim that time with piston TDC (top dead center).

The power source is self-generated by AC (alternating current) output. It is basically a magnet/AC generator that reads slots cut into the outside rim of the left-hand flywheel face. The faster the slots pass by the magnet-sensor the faster the flywheels are rotating and thus the faster the pistons are traveling. Furthermore, slot location determines where the flywheel rotation is relative to piston location. After all, this is about when to fire the spark plugs for maximizing combustion. An EFI system also links a fuel delivery *pulse width* table with the spark map for even more precise engine management. Pulse width is the length of time in milliseconds that the injectors activate to squirt fuel.

Manifold Absolute Pressure Sensor

The Manifold Air Pressure sensor (32316-99) is also known by the acronym MAP. It locates on top and extends into the manifold to read the constantly changing manifold absolute pressure changes of the air inside. This information transfers via electrical signal to the ECM, which consults the spark map cell matrix to determine appropriate advance-retard spark timing. Simply, manifold vacuum or no-vacuum indicates whether the bike is under load (cold idle, acceleration) or not (hot idle, cruising) This will determine when spark should occur during the latter stages of the engine compression stroke.

Bank Angle Sensor

Circa 1998, the Bank Angle Sensor (32495-98) or BAS switch relieves duty for the VAS (Vehicle Attitude Sensor). If the motorcycle tips, the BAS reduces the angle for engine shutoff from VAS 80-degrees to 55-degrees horizontal to the ground. This safety sensor is a magnetic ball that rides in a silicone fluid in a V shaped channel. If the bike tilts to within 35-degrees horizontal (35° + 55° = 90°) to the ground or less, the magnetic ball will ride up the channel creating an open circuit within the sensor. The power source is +5 volts from the ECM. This open circuit, in turn is detected by the ECM, which immediately turns off the ignition system. Once this sensor is tipped beyond 55°:

The bike must be brought back to an upright position.

1. Ignition key turned off.
2. Wait at least 10-seconds before turning the ignition on and restarting the bike.

The Evolution VAS sensor located in the engine's right side timing chest cover and mounted as part of the CMP sensor at the end of the camshaft on the sensor plate.

The Twin Cam BAS locates in various places like behind the left side cover on FLT rubbermount models.

Manifold

The carburetor manifold looks like the Evo's except it is a little wider to take up part of any gap previously left for the manifold rubber to seal.

The seal material upgrades to Viton, which remains pliant and resists cracking. The Evo rubber seals crack and become brittle with the hot temperatures.

1. There is also a hole for the MAP sensor to assist the engine management system.

Magneti-Marelli EFI Fuel Linking Ignition

EFI links the ignition table or spark map with a fuel table that coordinates precise fuel delivery with ignition advance or retard settings.

Electronic Fuel Injection may seem more complicated than carburetion but I think it is simpler since much of the physics necessary to understand carburetion is not needed.

The Intimidation Factor

I think what is so intimidating about EFI is that it takes a person out of the comfort zone and familiarity of carburetors into a new arena. There is a new:

1. Language to learn.
2. The specialty tools are foreign.
3. Diagnosing problems is done much differently.

In short, the mechanic must trade a screwdriver for an electrical diagnostic tool that plugs into the wiring harness. However, tuning a carburetor is an art as well as a science. EFI is simpler because it involves only science. There is no need for art where instinctual *feel* develops over twenty years of tuning. Therefore, once the mechanic embraces the new EFI mindset, learns the lingo, is shown how to use the tools, he or she will discover the simplicity relative to complex carburetion.

EFI evolved out of carburetion around three decades ago in order to meet specific emissions dictates with precise air-fuel-ratios for cold idle, hot idle, cruising, and acceleration. Carburetion was able to meet these requirements but the multitude of hoses and associated plumbing complicated the mechanism to the point an engineering degree was necessary for tuning. It was also one thing to have a carburetor buried in a plethora of tubing under the hood of a car but it sure would be impractical on the side of a motorcycle. Therefore, carburetion did meet initial, but strict EPA dictates quite successfully.

Reluctantly, carburetion can probably still do this up until 2010 EPA changes and perhaps past this date as evidenced with aftermarket engines achieving certification with various carburetors. However, it just became simpler to evolve into EFI, which is the current epitome of efficiency.

Harley-Davidson's first foray into EFI was certainly a learning experience with the inadequately sized 38mm Magneti-Marelli (MM) system fraught with problems such as air leaks and misdirected fuel injector angles. Expected power increases over the excellent CV Kehein carburetor did not materialize. I have never been a fan of this system even though I am a vocal proponent of EFI over carburetion for both efficiency and power increases.

Magneti-Marelli was used on all EFI Evolution models from 1995 to 1998 as well as early Twin Cams from 1999 to circa 2001 depending on model. Delphi EFI replaced MM and has not looked back with ongoing changes that just made Harley life better each year of use.

EFI: Ideal Fuel Delivery

EFI has so many advantages over carburetion. However, the driving force behind its use on Harley's is meeting government emissions controls.

- The precision of fuel delivery on an EFI system lowers harmful emissions and improves fuel economy.
- For those that want to learn, it can also do wonders for high-performance goals.

- Carburetors are finicky and imprecise. They cannot deliver the right amount of fuel and air for all rpm ranges and load demands on the engine whereas EFI can deliver precise amounts of gas and air at any rpm and at any load.
- Many argue that the Harley EFI system produces a slower bike than their carbureted counterparts. Well, it is true in the first few years. The Magneti-Marelli EFI systems introduced on selected touring models in 1995 were dogs in the performance end of things. As I proceed, this will become very evident because of a too-small diameter throttle body, injectors squirting gas into the wrong place, and air leaks.

EFI gradually improves over the years until it gains clear superiority in every facet of use with the introduction of the Delphi system on the 2001 Softails and the 2002 touring models. Check out a V-Rod or the discontinued Buell 1125R if wanting to see what EFI is capable of in the speed department while meeting emissions dictates.

EFI Benefits

1. Easy starting especially in adverse climatic conditions; just push the start button *without touching the throttle*. The ECM computer has already told the injectors to put more fuel in because of the cold start condition. The EFI equipped bike will start immediately while the poor old carbureted one must be choked and the throttle primed just right or there won't be enough gas or there will be too much to fire the engine.
    - Cold idle on EFI bikes may sound racy and there will be no ka-chugging at prescribed rates of 1500 rpm to 1600 rpm.
    - Hot idle slows down to 1050 rpm + or – 50 rpm.

This is a direct result of more gas being injected until the bike warms up. When warm the idle should be no lower than 950 rpm as the charging system and oil pressure to the bottom end bearings can be affected.

While adding numerous parts unfamiliar with a carbureted system like fuel pumps, solenoids and some sensors, EFI also eliminates the need for a cold start enrichment device, (choke), cable, and a gas petcock.

1. EFI compensates gas delivery for differing altitudes while most carburetors must be readjusted and may need jetting changes.

Air density refers to the amount of oxygen in the atmosphere. Gravity is what keeps the atmosphere around the earth. As gravity decreases at higher altitudes there is less-atmosphere.

As gravity increases as sea level approaches, the weight of the entire atmosphere compresses it giving the air more density. This of course provides more oxygen to mix with the fuel.

- Different temperatures also affect air density and therefore oxygenation capabilities.
- More or less air requires more or less fuel in order to have a proper mix for burning in the combustion chamber. Carburetors are hard pressed to accommodate air density differentials caused by barometric pressure and altitude without jetting changes.

1. EFI has sensors that measure barometric pressure and temperature to assist the computer with more information to meter the amount of fuel to inject into the intake ports.
2. More accurate fuel delivery under differing but specific engine loads and operating conditions is the big plus over the relatively wasteful carburetor.

How EFI Works: The Total Engine Management System

The Sequential Port Fuel Injection System is known simply as EFI. The first goal of electronic fuel injection is to determine through various monitoring sensors, engine conditions, engine needs, and environmental circumstances so that the ECM can address air/fuel mixture, injector delivery timing, and ignition timing.

EFI is more than Fuel Delivery

Thus the reader can infer that EFI is much more than fuel delivery. EFI is a total engine management system that:

Cares for protecting our environment.

Ensures a balanced air-fuel-ratio for various stages of engine running; cold idle AFR, hot idle AFR, cruising, and acceleration.

1. Time when the fuel delivery injectors turn on and for how long.
2. Coordinates ignition timing with fuel delivery so that the spark plugs fire at the most opportune time to achieve maximum combustion.

The beauty of EFI is that with engine management under its firm control, the minimum amount of fuel is utilized to produce maximum mileage efficiency while delivering greatest power. Why is this? Well, carburetion depends solely on the laws of physics in combination with fixed jets that overlap each other. Thus, carburetors cannot be totally efficient as constantly changing air density, humidity, and altitude amongst other factors must depend on unchanging jet orifices and air bleeds. The engine management system adjusts fuel delivery and spark timing according to the sensor information the ECM computer receives to balance all these factors almost instantaneously.

I ask the rhetorical question. On an inefficient internal combustion engine, what could possibly be better?

There are six main sensors that feed information to the MM ECM computer that contains the spark map matrix on timing when the spark plug should ignite. The sensors vary whether for carburetion or fuel injection. The seventh sensor is the Bank Angle Sensor or BAS (32495-98) that shuts ignition and fuel delivery if the bike tips over more than 55-degrees. BAS discontinues after use on early Twin Cam MM EFI but returns on TLE and TLEU sidecar models serviced by Delphi EFI in later Twin Cam years. I visualize tipping a motorcycle sidecar whopping 55-degrees before the BAS sensor/switch turns off ignition and fuel delivery…scary, but welcome.

The MM sensors with their short form acronyms are:

1. TP-Throttle Position sensor (27271-95).
2. CMP-Camshaft speed and position (32496-99).
3. CKP-Crank or flywheel speed and position (32497-99).
4. BARO-Barometer or pressure altitude sensor (32424-98).
5. IAT-Intake air temperature sensor (27270-95).
6. ET-Engine temperature sensor (32446-99)

Five other components are required for the MM fuel injected Twin Cam ignition system:

1. Battery
2. Ignition coil (single fire).
3. ECM-Electronic Control Module.
4. RFI (radio frequency interference) protected spark plug wires.
5. RFI spark plugs.

Single Fire Twin Cam Coils

After the sensor information computes, the ECM consults its spark map matrix to signal the ignition coil to spark the plugs. This ignites and burns the incoming fuel charge to produce the best efficiency in terms of power.

In the beginning, the new single fire Twin Cam coil (31639-99 FLT, 31655-99 Softail) fits all models with either CV carburetion or MM electronic fuel injection. Part numbers vary because of mounting considerations. Spark cable mounting is clearly marked F for front cylinder and R for rear cylinder. Dual fire coils have no spark plug cable mounting preference or requirement. By 2002, another coil (31743-01) evolved for EFI models and the existing coil part numbers (31639-99, 31655-99) remained for carbureted models. A new coil (31696-07A FLT) begins use in 2007 for EFI models with various part numbers that have more to do with mounting concerns than function.

All models including Sportster use Delphi EFI beginning in 2007 but whose earliest use was in some 2001 Softail models, notably the FLSTCI Heritage Classic, FLSTFI Fat Boy, FXSTSI Softail Springer, FXSTBI Softail Night Train and the FXSTDI Softail Deuce. The suffix I designates a fuel injected model as opposed to a carbureted one up until 2006. After 2007, the I-suffix is dropped since all models become equipped with EFI so the distinction between carbureted and EFI is no longer relevant.

Some of the following sensor material may seem repetitive but it has its nuances and is specific to MM EFI although it may also apply to CV carburetor application.

The Throttle Position Sensor

The Throttle Position Sensor (27271-95) also known as a TP sensor locates on the left-side, near the front of the MM induction module on the end of the throttle plate shaft. It is a variable resistor. Like a bar code or a rainbow, there are different values measured in volts from one end to the other. The resistance changes in relation to the position of the throttle plates. Simply the ECM feeds +5 volts to the sensor and reads the return DC (direct current) voltage. This sensor rarely shuts the system down if problems develop. Mercifully, it will let the rider limp home with a poorly running engine. The TP Sensor tells the ECM the angle of the two MM throttle butterfly plates in the induction module throat for air volume intake and spark plug ignition timing. In plain English, the induction module is the EFI body. The information is used for:

a) Fuel mixture.
b) Injector timing.
c) Ignition timing.

The Camshaft Position Sensor

The Camshaft Position Sensor (32496-99) also known by its acronym CMP locates in front of the timing cover incorporates a Hall effect Sensor. The Hall effect ignition pickup unit locates inside the timing cover. There is an incomplete semi-circular ridge on the outer side of the 34-tooth rear-cam-drive-gear. This ridge acts as the rotor. There is a break known as a window because the ridge (rotor) on the primary cam drive gear is not full circle. The ridge location, beginning and end give engine timing information as all interacting engine parts time to each other. As the ridge (rotor) on the cam gear turns with the rotating rear cam, it breaks the magnetic field of the Hall effect sensor. An electrical pulse is generated by the power source of +5 volts back to the ECM. The pulse instructs the ECM regarding engine phase, which in plain English is the position and speed of moving engine parts that time to each other. If the ECM knows the cam position, it will also know valve(s) positions relative to their seat(s) and piston location, which will also indicate crankshaft degrees rotation of the flywheels.

The Camshaft Position Sensor (CMP) is no longer used after circa 2001. The Crankshaft Position Sensor (CKP) takes on CMP function since it monitors flywheel position that time to other moving engine parts.

The Crankshaft Position Sensor (CKP)

The Crankshaft Position Sensor (32497-99) locates in the front of the left crankcase half above the alternator plug. It measures and sends information to the ECM regarding engine speed and location. The methodology for deriving this information is from magnetically reading the 30-indent cut teeth in the left side flywheel as it rotates with the crank. There are two missing teeth cuts in the flywheel rim. This area times with piston TDC (top dead center).

The CKP is a magnet/AC generator that reads slots cut into the outside rim of the left-hand flywheel face. The faster the slots pass by the magnet-sensor the faster the flywheels are rotating and thus the faster the engine rpm. Furthermore, slot location determines where the flywheel rotation is relative to piston location. After all, this is about when to fire the spark plugs for maximizing combustion. An EFI system links a fuel delivery *pulse width* table with the spark map for even more precise engine management. Pulse width is the length of time in milliseconds that the injectors activate to squirt fuel.

Barometric Sensor

The Barometric Pressure Sensor (32424-98) is also known by its acronym BARO monitors altitude by measuring atmospheric pressure. The ECM can alter fuel delivery to compensate for more or less air (oxygen) depending on altitude. It uses a Piezoresistive circuit. Whoa, that's a mouthful isn't it? The Piezoresistive effect describes the changing *electrical resistance* of a material due to applied *mechanical stress*. In simpler language, the Piezoresistive effect only causes a change in electrical resistance. Therefore we can use the amount of electrical resistance to measure the mechanical stress or pressure of the atmosphere to determine altitude. Sea level atmospheric pressure is about 14.7 lbs/in^2 and reduces in lbs/in^2 pressure as altitude increases because the effect of gravity lessens. The power source is +5 volts from the ECM. The ECM reads the return electrical voltage from the Piezoresistive circuit to determine altitude since:

A reading of 3 volts will indicate an altitude of 13,000' (3960m or meters).

a) A reading of 4.8 volts will indicate an altitude of 0' (0m) at sea level.

The BARO Sensor locates in various places. On the FLT models it can be found behind the ECM bracket underneath the right side cover.

Intake Air Temperature Sensor

The Intake Air Temperature Sensor (27270-95) or IAT sends the ECM data about the temperature of the air entering the engine via the induction module (EFI body). The IAT locates in the center, left side of the rear cylinder intake runner of the MM induction module. The IAT utilizes a thermistor, which changes resistance relative to temperature present. Thermistor is a word combination of thermal and resistor. The ECM feeds +5 volts to the IAT sensor and reads back the sensor's circuit voltage via the thermistor. The extremes are 0.2 volts indicates an intake air temperature of 257° F while an ECM read back of 4.9 volts indicates an IAT temperature of -40° F. The feedback IAT information is used in conjunction with the Barometric Pressure Sensor (BARO) to determine air density and thus oxygen content for fuel delivery rates during cold startup, cold idle and hot idle.

Engine Temperature Sensor

The Engine Temperature Sensor (32446-99) or ET reports engine temperature of the front cylinder head to the ECM; the ET threads into the left rear of the front cylinder head sometimes known as the *chimney.*

This sensor contains a *thermistor,* whose resistance varies with temperature. Therefore, the resistance of the thermistor can accurately inform the ECM of engine temperature. Like the IAT, the ECM feeds +5 volts to the ET and reads back the sensor's circuit voltage via the thermistor. The extremes are 0.2 volts indicates an engine temperature of 257° F while an ECM read back of 4.9 volts indicates an engine temperature of -40° F. The feedback ET information is used:

a) For idle speed adjustment while the engine is warming. Cold idle engine rpm is higher than hot idle.

b) To help determine EFI injector *pulse width.* Fuel injectors have a fixed amount of gas passing through them. Therefore fuel amount can be increased or decreased by the time or pulse width that the injectors are squirting.

Bank Angle Sensor

The Bank Angle Sensor (32495-98) or safety BAS switch discontinues before the change from MM EFI to Delphi EFI except for use on Delphi EFI TLE and TLEU sidecar models.

If the motorcycle tips, the BAS angle for engine shutoff is 55° horizontal to the ground. This sensor is a magnetic ball that rides in a silicone fluid in a V shaped channel. If the bike tilts to within 35-degrees horizontal (35° + 55° = 90°) to the ground or less, the magnetic ball will ride up the channel creating an open circuit within the sensor. The power source is +5 volts from the ECM. This open circuit, in turn is detected by the ECM, which immediately turns off the ignition system. Once this sensor is tipped beyond 55°:

1. The bike must be brought back to an upright position.
2. Ignition key turned off.
3. Wait at least 10-seconds before turning the ignition on and restarting the bike.

The Twin Cam BAS locates in various places like behind the left side cover on FLT rubbermount models.

The Magneti Marelli electronic fuel injection is basically the same as the Evolution setup that began use in 1995 on some FLHT models, but the injectors (27135-97) are the former override performance ones. They are larger to accommodate the extra Twin Cam cubic inches but are still too small.

Twin Cam Engine Management Sensors [1]

Sensor	CV Kehein Carburetor 1999 to 2006	Magneti-Marelli EFI 1999 to 2001	Delphi EFI 2001 to present
Cam Position: CMP	32496-99	32496-99	-
Crank position: CKP	32497-99	32497-99	32789-00/32707-01C
Manifold Pressure: MAP [2]	32316-99	-	32316-99
Manifold Pressure + Temp: TMAP	-	-	32319-07
Bank Angle Sensor: BAS [3]	32495-98	32495-98	32495-98 TLE/TLEU
Barometric: BARO [4]	-	32424-98	-
Throttle Position: TP	-	27271-95	27629-01/27659-06
Twist grip sensor (fly-by-wire) [5]	-	-	32305-08
Intake Air Temperature: IAT	-	27270-95	27270-95/27381-06
Engine Temperature: ET	-	32446-99	32446-99
Oxygen (O_2) Sensor	-	-	27719-07; 27683-07

[1] There are other sensors on a Twin Cam that have separate functions from engine management like the Vehicle Speed Sensor (74419-96 etc.) in the transmission casing that services the speedometer/odometer and the Oil Pressure Sensor (26561-99) connecting to a dash light that indicates if there is satisfactory oil pressure in the Twin Cam engine.

[2] The new 2008 TMAP sensor (32319-07) replaces the pressure only MAP sensor, now combining intake air temperature (IAT) readings with manifold air pressure.

[3] The Bank Angle Sensor (BAS) is found with early model CV carburetors and Magneti-Marelli EFI but discontinues except for use of TLE and TLEU sidecar models using Delphi EFI.

[4] Manifold Absolute Pressure is also known as Manifold Air Pressure. MAP seems almost the same as the Barometric Pressure Sensor (BARO) but is not. MAP monitors artificially-induced air pressure travelling through the manifold. This pressure varies because of speed of air travel dictated by the narrowing venturi (Bernoulli's Principle) and the vacuum created by descending pistons. BARO measures barometric pressure or naturally occurring air density (weight) that decreases with altitude.

[5] TP-Throttle Position Sensor that was part number 27271-95 for MM EFI now becomes 27629-01 and later 32707-06 for the mechanical throttle actuator. However, it discontinues after 2008 with the introduction of the electronic fly-by-wire throttle. A new throttle sensor called a twist grip sensor (32305-08) ably takes over.

Delphi EFI Fuel Linking Ignition

Delphi EFI was and is a huge improvement over the inefficient, too small Magneti-Marelli EFI. The MM EFI looks mean with its dual runners, one for each cylinder but the throat sizing was a meager 38mm. Delphi began use between the 2001 Softails and the 2002 touring models. The single induction module throat was larger than the MM throats growing to 46mm in 2007. I explore these areas in great detail in Volume II: *Performancing the Twin Cam* in Chapter IX: *Fuel Delivery.*

The Delphi sensors with their short form acronyms are:

TP-Throttle Position sensor (27629-01 and 32707-06) services the mechanical throttle actuator until the 2009 advent of fly-by-wire electronic throttle.

1. CKP-Crank or flywheel speed and position (32789-00 32707-01, 32707-01A 32707-01B, and 32707-01C).
2. MAP-Manifold Absolute (or Air) Pressure sensor: 1999 to 2007 (32316-99).
3. TMAP-Manifold Absolute Pressure and Temperature sensor (32319-07) on 2008-to-present models replaces the MAP sensor and adds a temperature function (IAT).
4. IAT-Intake air temperature sensor: 1999 to 2007 (27270-95 and 27381-06).
5. ET-Engine temperature sensor (32446-99).
6. The 2006 Dyna and all model 2007-to-present Oxygen (0_2) Sensor (FLT 27719-07 front exhaust; 27683-07 rear exhaust).
7. ETC-Electronic Throttle Control sensor (32305-08) introduces in 2009 and locates by the handlebar twist grip. This fly-by-wire electronic throttle control eliminates the need for manual throttle and idle cables.
8. BAS-Bank Angle Sensor (32495-98) found on TLE and TLEU sidecar models.

Five other components are required for the three main versions of the Delphi fuel injected Twin Cam ignition system:

1. Battery
2. Ignition coil (single fire).
3. ECM-Electronic Control Module.
4. RFI spark plug wires.
5. RFI spark plugs.

I cover some of these sensors in the previous Magneti-Marelli section. However, some part numbers for the various sensors change because they have different mounting on the Delphi EFI from those on the MM EFI, the introduction of the TC96 in 2007 with changes occurring the year before, and upgrading of the sensor itself. The changes are:

1. TP-Throttle Position sensor that was part number 27271-95 now becomes 27629-01 and later 32707-06. However, it discontinues after 2008 with the introduction of the electronic fly-by-wire throttle also known as Electric Throttle Control (ETC). A new throttle sensor called a twist grip sensor (32305-08) ably takes over.
2. CKP-Crank or flywheel speed and position sensor that was part number 32497-99 now becomes 32789-00 and later after 2001 changes to 32707-01, 32707-01A, 32707-01B, and finally 32707-01C.
3. MAP-Manifold Absolute (or Air) Pressure sensor (32316-99) retains the same part number as that used on the CV carburetor until 2007 when it obsoletes and replaces by a TMAP sensor (32319-07). Furthermore, on a different but related subject, the service manuals begin to confuse the issue by sometimes calling the MAP sensor a BARO/MAP or simply a BARO sensor all using the same part number originally assigned the MAP sensor.

4. TMAP sensor (32319-07) combines manifold air pressure (MAP) with intake air temperature (IAT) beginning in 2008 and continuing to present.
5. IAT-Intake air temperature sensor retains the same part number as with MM EFI (27270-95) but changes later to 27381-06. However, IAT discontinues but combines in function with the TMAP sensor.
6. ET-Engine temperature sensor (32446-99)
7. BAS-Bank Angle Sensor (32495-98) is now found on TLE and TLEU sidecar models but retains its same part number as with the CV carburetor and MM EFI.
8. Oxygen (0_2) sensor(s) first come into use with the 2006 Dyna models and find use in all models from 2007-to-present. Part numbers for 2007 touring are 27719-07 front exhaust and 27683-07 rear exhaust. Oxygen sensors become smaller in 2010 but perform the same closed loop EFI functions

The MAP sensor is back for Delphi EFI with the BARO sensor being dropped. I will review the MAP sensor functions.

Manifold Absolute Pressure Sensor

MAP is also known as the Manifold Air Pressure sensor (32316-99). It locates on top of the intake manifold. It extends into the manifold to read the constantly changing manifold absolute pressure changes of the air inside. This information transfers via electrical signal to the ECM, which consults the spark map cell matrix to determine appropriate advance-retard spark timing. Simply, manifold vacuum or no-vacuum indicates whether the bike is under load (cold idle, acceleration) or not (hot idle, cruising), which determines when spark should occur during the latter stages of the engine compression stroke. The new 2008 sensor (32319-07), the TMAP sensor replaces the pressure only MAP sensor, now combining temperature readings with manifold air pressure.

Oxygen Sensors, a Stoichiometric Air-Fuel-Ratio, and Closed-Loop EFI

Magneti-Marelli EFI and Delphi EFI from 1995 to 2006 are known as open loop systems because there is no continuous feedback from the whole system to the ECM for fuel and ignition settings. There is feed information of existing conditions but no feed from resultant conditions such as exhaust gas composition. The advent of oxygen sensor(s) locating in the exhaust pipe(s) complete the system by giving feedback to the ECM thus closing the loop.

In 2006, the Dyna models receive an oxygen sensor in the exhaust pipe to read exhaust composition for feedback to the ECM. In 2007, all Twin Cams receive oxygen sensors to create a closed-loop EFI system. Closed-loop EFI simply means that during hot idle and cruising modes the air-fuel-ratio is Stoichiometric 14.7:1. The Stoichiometric ratio defines as the optimum air-fuel ratio, where all the available oxygen in the air combines with all the available fuel for burning in the combustion chamber. In other words there is the most complete combustion possible with 14.7 parts air with one part gasoline burning the greatest pollutants possible. Stoichiometric AFR is possible with a closed loop system because the exhaust gases will indicate maximum combustion or partial combustion due to either a too-rich or too-lean condition.

Stoichiometric AFR for maximum combustion is different for various fuels; gasoline is 14.7; diesel is 14.6; Methanol is 6.4 while ethanol is 9.0. Reformulated gasoline and ethanol additions also slightly change this 14.7:1 ratio.

However, a richer AFR ratio than 14.7:1 is required for engine load conditions such as cold idle starts and warm up as well as with hard acceleration. Therefore, open loop EFI occurs at cold idle and during acceleration, when the AFR necessarily must be richened, adding more gas. Idle needs a richer gas ratio to allow the bike to warm up while acceleration demands more gas for power. Open loop with an AFR of less than 14.7:1 is wasteful in terms of emissions but necessary for load conditions, while a closed-loop AFR ratio of 14.7:1 is theoretically the best for burning all the emissions during no-load situations. In a closed loop system, load conditions require a richer AFR but the no-load conditions of hot idle, gentle acceleration, and cruising use an AFR of 14.7:1.

The modern adaptive learning engine management system that integrates spark timing with fuel delivery via information sent by various sensors like the oxygen sensors is a sophisticated and yet simple coordinated system. It controls the combustion Stoichiometry by monitoring various engine considerations including the exhaust oxygen sensor outputs. The oxygen sensors allow the creation of a closed loop EFI fuel delivery system that monitors and adapts to compensate for changes in fuel content and air density by adjusting the air-to-fuel ratio. Exhaust catalysts that introduce in Harley-Davidson 50-State models in 2010 are a further refinement to achieving the most efficient air-to-fuel ratios.

Therefore, the closed-loop feedback-controlled fuel injection varies the fuel injector on-time or pulse width according to real-time sensor data rather than operating with a predetermined open-loop fuel map. In addition to enabling electronic fuel injection to work efficiently, this emissions control technique can reduce the amounts of both unburned fuel and environmentally dangerous oxides of nitrogen (NO_x) and air-borne hydrocarbons from entering the atmosphere.

The O_2 sensor does not actually measure oxygen concentration but rather the amount of oxygen needed to completely oxidize (burn) any remaining combustibles in the exhaust gas. A rich exhaust gas mixture requires an oxygen demand. This rich exhaust gas composition causes sensor voltage to build up, due to the permeation of oxygen ions through the sensor layer. Conversely, a lean mixture causes low voltage, since there is an oxygen excess. The voltage status information on exhaust gas oxygen concentration is sent via wiring electrical impulse to the engine management module, which adjusts the amount of fuel injected into the engine to compensate more fuel for a lean situation or less fuel for a rich exhaust composition circumstance. The ECM attempts to maintain, on average, a 14.7:1 air-fuel-ratio by interpreting the voltage information it gains from the oxygen sensor. The ECM adjusts the quantity of fuel accordingly and hopefully will read a resulting change in the voltage-response of the oxygen sensor. This closed-loop information forces the engine to operate both slightly lean and slightly rich on successive loops, as the ECM constantly juggles to maintain a Stoichiometric AFR ratio on average during hot idle, gentle acceleration, and cruise no-load situations.

The three types of main pollutants that a Harley-Davidson gasoline engine closed loop engine management system attempts to control are:

1. Hydrocarbons, which flow out as exhaust emissions when the gasoline AFR is rich and does not burn completely.
2. Carbon monoxide (CO), which is also the result of running slightly rich.
3. Oxides of Nitrogen (NO_x), which dominate when the AFR mixture is overly lean.

The ECM: Electronic Control Module

The ECM is the main computer that runs the engine management system and thus EFI. It is known by other names in Harleyese that may confuse the reader so I will list some of them here.

- ECU or electronic control unit.
- ICU or ignition control unit
- The computer.
- The brain.
- Magic box (this may also be a colloquialism for the unrelated charging system rectifier/regulator).

All Evolution and Twin Cam Harley-Davidson's including carbureted models have an ECM but total engine management is the forté of electronic fuel injected models. Carburetor integrated ignitions, broach engine management but not to the level that EFI does.

The Twin Cam touring model Magneti-Marelli ECM locates under the right side cover along with the power 40amp circuit breaker (74600-97A, 72314-01) and fuel pump fuses, the Barometric Pressure Sensor if used, and the Data Link Connector for plug-in diagnosis with special EFI tools. The ECM will locate in different places over the Twin Cam years depending on model.

H-D goes to great and satisfactory lengths to protect the main computer (ECM), which includes rubber mounting to protect against vibration. It also has a durable sealing exterior to protect against you, the rider's obsession with cleanliness through the use of high power spray hoses as well as road dirt.

The power source for the ECM is via the battery and the main wiring harness through the 40-ampere (amp) circuit breaker or fuse, the ECM relay and the ECM fuse. The ECM basic functions are controlling the operation of:

1. The fuel pump.
2. Fuel injectors.
3. Ignition coil.

Again, the various *input* sensors provide the information to the ECM for constantly changing but programmed computer *output* fuel and spark delivery according to conditions at that point in time.

Primary Sensors

Suitable engine performance depends on three input sensors:

1. Throttle Position (TP) Sensor.
2. Camshaft Position (CMP) Sensor (Magneti-Marelli only).
3. Crankshaft Position (CKP) Sensor.

An argument can be made that the new ETC-Electronic Throttle Control sensor (32305-08) that introduces in 2009 and locates by the handlebar twist grip is a primary sensor. The fly-by-wire electronic throttle control eliminates manual throttle and idle cables and thus becomes essential.

Secondary Sensors

Fine tuning engine performance but not absolutely necessary for basic running (limp-home mode) are three or four, or five additional input sensors depending on year:

1. Barometric Pressure (BARO) Sensor (Magneti-Marelli EFI).
2. Manifold Absolute (Air) Pressure (MAP) Sensor (Delphi EFI)
3. Intake Air Temperature (IAT) Sensor.
4. TMAP sensor (32319-07) combines manifold air pressure (MAP) with intake air temperature (IAT) beginning in 2008.
5. Engine Temperature (ET) Sensor.
6. The 2006 Dyna and all model 2007-to-present Oxygen ($0_{2)}$) Sensor (FLT 27719-07 front exhaust; 27683-07 rear exhaust).

The reader will see the term *ambient* used in connection with sensors and temperature. Ambient defines as in the immediately surrounding area.

The ECM gathers and reads input sensor data. It interprets all the input data and sends output signals to operate:

1. The fuel injectors by turning them on for a specified period of time (pulse width).
2. The single fire ignition coil to initiate spark plug firing.
3. The idle speed control actuator.
4. The check engine lamp if necessary.
5. Electrical relays.

EFI Components

The Twin Cam/Evolution EFI gas tank is very much different from a carbureted one. They are not interchangeable.

It would be a work in frustration and expense to convert a carbureted gas tank into an EFI ready one. However, all of the internal fuel tank components for EFI can be moved outside of a carbureted tank with aftermarket offerings. It is easier but expensive to begin with an H-D or aftermarket EFI fuel tank.

- Converting an EFI tank for conversion to a carbureted system is easily done with a simple aftermarket conversion kit.

Fuel Supply Components

1. Fuel pump (61342-95 MM; 75126-02B, 62908-08 Delphi) and associated wiring; a fuel pump inside the gas tank keeps pressurized fuel at the ready all the time.
2. Fuel pressure regulator is inside the gas tank on Delphi EFI (27408-01, 61015-04A) but locates on the outside rear of the induction body of MM EFI (27219-95A).
3. The fuel-pump isopod (62163-01B) which is an internal bracket that supports and holds the fuel pump. Some isopods are integral with the fuel tank and thus do not have a separate part number.
4. Internal fuel hose (62358-95 MM; 62357-00) connects the fuel pump to the gas filter.
5. Fuel (gas) filter canister. (61343-95 MM; 61001-01, 61011-04A Delphi)
6. An internal fuel hose connects the inside tank gas filter to the internal fuel supply tube (62357-95 MM; 75269-08 Delphi).
7. Inside fuel tank supply line tubing.
8. Supply check valve (61408-95A MM; 62228-03 62228-08A Delphi).

Some components like a fuel line may be integral with a part it serves on some years and models. Consult your manual for year and model for specifics.

Fuel tank Return Components

1. Return check valve (61407-95A MM).
2. Internal return line tubing that flows into the gas tank.

Some components like a fuel line or check valve may be integral with a part it serves on some years and models. Consult your manual for year and model for specifics.

Fuel Tank Access and Fuel Gauge Components

Gas tank canopy (75069-95 MM; 75110-04 Delphi) that allows access to the fuel tank is at the top, front center of the fuel tank. The gas cap bung, the evaporative bung fitting, gasket and hold down screws comprise and form part of the canopy.

1. Gas cap (61272-92B all MM and Delphi).
2. Fuel gauge sending unit (75701-95 MM).
3. Fuel gauge float, which is sometimes integral with the fuel gauge sending unit.
4. Fuel Level Sensor Float is part of the fuel gauge but not considered part of the engine management system.

Some components like a fuel gauge float or canopy may be integral with a part it serves on some years and models.

Induction Module Components

The aluminum 38mm MM Induction Module (27202-99) that distributes both air and fuel to the engine cylinders has twin runners, one for each cylinder. The Delphi module has a single runner. The runner(s) is the equivalent of a carburetor throttle body but both MM and late Delphi EFI systems have an integral manifold. Early Delphi induction systems employ a separate manifold. CV Kehein carburetor manifolds are separate. I am going to first list the MM components in order, as if looking at the front of the induction module on the bike from the front left side.

Magneti-Marelli Induction Module Components

The MM Induction module supports and houses the:

1. The Throttle Position Sensor (27271-95) known as the TP or TPS is on the front left side.
2. The Intake Air Temperature Sensor (27270-95) known as the IAT is almost midway, behind the TPS.
3. The fuel fitting (27221-95) for the gas tank supply fuel line to attach is top center of induction module behind the IAT.
4. Two fuel injectors (27135-97), one for each cylinder; the Magneti-Marelli (1995-2001) injectors do not point straight at the intake valves as one might assume. They locate left and right top center near the induction module rear but in front of return fuel fitting.
5. The fuel pressure regulator (27219-95A) that controls fuel pressure from the internal gas tank fuel pump locates at the rear of the induction module.
6. The return fuel fitting (27221-95) for the low-pressure return fuel tank gas line to attach is center, rear top behind the injectors.
7. Idle Speed Control Actuator (27272-95A) sits on the right side, midway closer to the front, opposite the IAT.

8. Idle speed cam lever plate kit (27593-98) is part of the throttle plate linkage on the front right side.
9. The throttle butterfly plates inside the dual runner induction module throats and the associated linkages including the throttle control levers. These form part of the induction module and do not have separate part numbers.
10. There are also O-rings, gasketing, manifold seals and the cold/hot idle set screw (27217-95A).

Early Delphi Induction Module Components: 2001 to 2005

The 2001 to 2005 Delphi induction module (27603-01) has a separate manifold (27630-01). The joined induction module and manifold supports and houses the:

1. The idle kit (27628-01) with an air control, hardware and an idle control sits top front center on the induction module.
2. The Throttle Position Sensor (27629-01) or TP or TPS sits on the front left side of the induction module.
3. The Intake Air Temperature Sensor (27270-95) or IAT sits on the front left side of the induction module.
4. The MAP sensor (32316-99) locates at the front top center of the intake induction manifold.
5. A throttle cable housing stop (27604-01A) sits near the left side rear of the induction manifold.
6. Two fuel injectors (27609-01 set of 2 and superseding 27609-01A set of 2), one for each cylinder sit left and right top center by the induction module's separate rear manifold.
7. The fuel rail (27608-01) or fuel line fitting services both injectors.

Mid-years Delphi Induction Module Components: 2006 to circa early-2008

The 2006 to circa early-2008 46mm Delphi induction module (27708-06) has an integral manifold and supports and houses the:

1. The air control kit (27658-06) with an idle control, hardware, an idle control and motor sits top front center on the induction module.
2. The Throttle Position Sensor (27659-06) known as the TP or TPS sits on the front left side of the induction module.
3. The Intake Air Temperature Sensor (27381-06) known as the IAT sits on the front left side of the induction module.
4. The MAP sensor (32316-99) locates at the top center of the induction module.
5. A throttle cable housing stop (27684-06) sits near the left side rear of the induction module.
6. Two fuel injectors (27709-06A), one for each cylinder sit left and right top center by the induction module rear integral manifold.
7. A fuel rail (27651-06) or fuel line fitting kit that includes the fuel rail, hardware, and purge tube services both injectors.

Late Delphi Induction Module Components: late-2008-to-present

The circa late-2008 to present Delphi induction module (27685-08A) has an integral manifold and supports and houses the:

1. Servo motor for the fly-by-wire electronic throttle, (front lower and left side).

2. TMAP sensor or manifold air pressure-temperature sensor (32319-07) on the rear left side.
3. Two fuel injectors (27609-01B), one for each cylinder sit left and right top center by the induction module rear integral manifold.
4. A fuel rail (27721-08) or fuel line fitting services both injectors.
5. There is an integral induction module purge tube centered in front of both injectors.

2011 Throttle Body Changes

In 2011, the Touring FLT Model throttle body is die cast. It is more compact than the earlier fly-by-wire throttle body. There is smaller throttle control motor (servomotor) housing. New calibrations are required. There are also new fuel lines. The 2011 throttle body will *not* retrofit to earlier models.

There are two fuel vapor emission purge system ports at the front and top left of the throttle body on Softail and Dyna Glide Models. The rear one is gray in color and acts as an active purge for Softail models. The front one is black and acts as a passive purge for Dyna models. The two ports are capped for jurisdictions with less onerous emissions dictates.

Air Cleaner

The Twin Cam air cleaner looks custom and for once, Harley riders might not change it, but, of course, that would be a hard habit to break. It has rounded points, front, and rear.

It allows more volume of air for both performance reasons and noise emissions reduction. More air equals less intake noise.

1. The air-breather intake hole moves to the front, similar to the Sportster location, to get cooler, as opposed to heated, air.
2. Another main feature is a flattened backing plate instead of the Evolution wraparound one in order to allow more cooling air to go past the fat cylinder fins.

Air Cleaner Components

1. Backing plate.
2. Two hollow breather screws (29645-99, 29465-08) that allow engine vented air to flow into the air breather.
3. Two breather tubes (29476-99, 29502-08) that attach to the breather bolts.
4. Filter element.
5. Front cover breather housing.
6. Fasteners and seal gasketing to hold it together as well as to the induction module.

Other Associated Components

- The various sensors and ECM are covered in the previous sections.
- Wiring.
- Relays.
- Fuses.
- Check engine lamp.
- Connectors.

Pressurized Fuel Delivery

Fuel is kept under pressure in order for instant availability. Excess gas simply pumps back into the fuel tank. There is no lag time with EFI. Appropriately, the jargon for this is *injector on time.*

This contrasts with carburetion where atmospheric pressure differences draw in gas that must also vaporize, which is a relatively slow process. Intake manifold pressure is a measurement of the flow of air through the throttle body venturi and intake manifold. Suction from the descending piston on the intake stroke initiates the flow of air through the fuel delivery system. A carburetor creates a partial vacuum to draw fuel into the air. Carburetion is comparatively slow and inaccurate relative to the instant precise reaction time in a fuel injected system.

EFI Fuel Injectors

Electronic Fuel Injection delivers fuel under pressure by a pump to gizmos called fuel injectors. Injectors introduce fuel as a pressurized spray. There are two separate fuel injectors in a production Harley engine, one for each cylinder. The longer an ejector nozzle holds open will determine the amount of fuel sprayed/squirted/injected, take your pick.

- Delphi (2001 to present) systems inject fuel onto the back of the intake valves just as they open and into their respective cylinders. Later Delphi EFI systems changed injector angles from 8^0 to a more proper 25^0.
- The early Harley Magneti-Marelli EFI systems (1995 to 2001) spray the fuel onto the inside throttle body near the intake ports but this is silly since more efficiencies and speed develop by squirting it directly at the backs of the opening intake valves.

Twelve volts of electricity are sent to each injector as soon as the ignition is turned on and the starter button is pushed in order to start the bike. There is an electromagnet inside each injector. It *grounds* when a transistor inside becomes energized thereby opening the injector valve or nozzle. The ECM dictates injector pulse width.

EFI Injector Pulse Width

The time the injector valve is open is called the injection *pulse width.* The pulse width extends when the ECM requires more fuel.

- This *on- time* or *width* measures in milliseconds (thousandths of a second).
- Idle requires three or four milliseconds of pulse width.

The pulse width of the injectors increases providing more fuel as the bike's engine load increases. This all determines by the ECM, whose computer processor receives sensor information, refers to the memorized fuel and spark tables that select injector pulse width and amount of spark advance or retard for ignition.

- The ECM has the ability to change pulse width over a hundred times per second.

Compare this with the barometric pressure and vacuum response time of a carburetor that will require full seconds not hundredths of a second. EFI is a long way from a carburetor when information dictating fuel spray is processed in less than a hundredth of a second and volume is measured in delivery per thousandths of a second.

I try not to beat up on carburetors because I like you have affection for them but I find it difficult to do so when writing comparisons.

EFI Specialty Tools

I am going to use Magneti-Marelli as the primary example for required servicing tools. As always, ongoing change occurs. Some tools like the Scanalyzer bridge carbureted engine management systems, Magneti-Marelli EFI and service Delphi EFI until circa 2006. Basic mechanical tools pretty much remain the same but electrical diagnostic tools go through evolutionary and sometimes revolutionary change. From circa-2006-to-present ECM Flash Reprogramming from a new sophisticated hardware/software/Intranet tool called Digital Technician can be downloaded to the motorcycle instead of using Scanalyzer cartridges with selected ECM calibrations stored on the hard drive.

Revolutionary change is easily characterized by the carburetor screwdriver tuning tool of choice to suddenly being confronted with an EFI electronic scanalyzer and breakout box superseded once again by Digital Technician technology. Fiddling is no longer an option.

Evolutionary change can be insidious. Once acclimatizing the mechanic who now becomes a technician and comfortable with the diagnostic capabilities of the scanalyzer, the ballgame changes once again. The scanalyzer becomes defunct. Is this because the dastardly aftermarket keeps horning in and must be contained?

Information is now passed through computerization and the exclusive Harley-Davidson Intranet. The technician plugs into the diagnostic port on the modern Harley-Davidson and the shop computer begins *talking* with the mainframe mother computer in Milwaukee. All information collected by the ECM downloads to the mother computer. Milwaukee now knows the motorcycle's history. The mainframe computer analyzes and gives solutions to the shop technician that may be thousands of miles away. Please see Chapter XI: *Twin Electrics*, section *2011 Digital Technician: Modern Diagnostics* for much information on this subject concerning TechLink , Digital Technician I (circa 2005 to 2011) and Digital Technician II, introduced with the 2011 Softail line-up.

However, the aftermarket rides to the rescue for the oppressed little guy or are they stealing from Harley-Davidson's jealously guarded market domain? I am not taking sides but I understand both and know each of their compelling arguments well. Anyway, the aftermarket supplies equipment that is currently able (2011) to diagnose and cure what ails yer new Twin Cam. I am being vague because information that I could supply will become dated very quickly in this fast changing game of cat and mouse. Current companies like Power Commander (www.powercommander.com), Daytona Twin Tec (www.daytona-twintec.com) and Zippers (www.zippersperformance.com) are all on top of their game.

The tools necessary to monitor the Magneti-Marelli EFI engine management system activate various components for diagnosing purposes; retrieve information known as *trouble codes*, and finally what to do with the trouble codes. This is part of the intimidation factor of electronic fuel injection. These tools carry over use into the Delphi systems with updates. Consult your manual for your year and model.

I get excited with EFI and its potential, which makes learning about different aspects like the traditionally unusual kinds of tools a stimulating challenge. Of course, EFI is not about hanging in the past with tradition but it is concerning progress into the future to effectively deal with traditional problems. Enough of the pep talk; let's get learning.

There are two main tools:

1. The scanalyzer, which diagnoses engine management problems.
2. The breakout box, which diagnoses wiring harness issues.

Always make sure the battery has a full charge to ensure accurate readings.

Scanalyzer

This scanalyzer (HD-41325) tool will diagnose all carburetion and EFI from 1995 to 2006. The mechanic need not worry about setting the scanalyzer for whichever fuel delivery system is in use. Once the scanalyzer plugs in and the software cartridge loads in the base, it will identify the fuel delivery and will show only information and testing as it relates to that system. Basically, the scanalyzer is a portable electrical tool that has a 25-pin female plug on the top end.

A cable with a male 25-pin connector plugs into the scanalyzer (DB-25 connection port) and then connects via a 4-way Deutsch connector into the *Data Link Connector* on the bike. I give the correct names, not to intimidate and confuse but to get the reader used to this new terminology that is descriptive once adjusted to the lingo.

- The Data Link Connector is found beside the ECM under the right side-cover underneath the motorcycle seat using FLT location as an example.
- There is also a round 4-pin female connector beside the DB-25 connection port into the top of the scanalyzer for a small data printer called a Weigh-Tronix printer (No. 3315) that looks like a calculator with the narrow tape for the printer paper.
- This cable can also hook to a now obsolete Wyse WY-60 computer monitor...you know, one of those old green phosphorus monitors. I know, I don't get it either.
- More importantly, a diagnostic software cartridge connects into the bottom end of the scanalyzer.
- The scanalyzer has the following diagnostic choices:

1. Active Diagnostics.
2. Trouble codes.
3. Special testing.
4. Calibration.
5. System identification (type of EFI or carburetion).
6. Tool setup.

Yeah that's nice but what does it really diagnose. Let's look at Active Diagnostics, which will diagnose among other things problems with the fuel pump, each fuel injector separately, each single fire coil separately and the tachometer. The ECM will save specific trouble codes in its memory for the scanalyzer if it detects a sensor related problem. Think about the last two statements. There is a whole lot of analyzing and diagnosing going on for a whole bunch of parts all by one tool *in a few seconds!* Once the reader/mechanic adapts to EFI it can give a very comfortable feeling.

Scanalyzer Diagnostic Application Cartridge

Well, that is a mouthful. The changeable cartridge (41325-95, 41325-95A, 41325-95B, 41325-95C) plugs into the base of the scanalyzer to complete the diagnostic tool. The original 41325-95 cartridge and the upgrade cartridges listed above will update any information required for system diagnosis. The 41325-95B cartridge covers all Evolution Magneti-Marelli as well as the first Twin Cam years. The 41325-95C continues into the Delphi applications.

Diagnostic Code Light

The Diagnostic Code Light (HD-41197) reads error codes from the ECM if the mechanic does not have a scanalyzer, which makes this an inexpensive cool tool for riders who like to do their own work. Use it when the engine light comes on. It attaches to the 4-pin diagnostic code connector by the ECM. Ignition must be turned to the ON position. Carefully count the number of flashes and pauses emitting from the diagnostic code light. For example 4-flashes followed by a pause followed by one flash will indicate trouble code #41. Consult your manual to determine that #41 indicates a problem with the CKP Sensor (Crankshaft Position Sensor) that locates at the front of the left-side engine case above the alternator plug.

EFI Harness Connector Kit

The EFI Harness Connector Test Kit (HD-41404) is a wonderful tool to test for connector and wiring electrical flow, shorts, and internal wire/connector breakage. The harness connector kit is a huge improvement for checking the wiring harness for problems. It includes jumper wires and probe connectors to use in conjunction with another tool called a DVOM (Digital Volt Ohm Meter). A DVOM measures voltage, which is the pressure of electricity traveling through a wire and ohms, which is the resistance of electricity. Another name for this DVOM is the Fluke 78 Multimeter (HD-39978). H-D uses both names in their manuals. If the reader does not know they are the same tool, life will get confusing very quickly.

Breakout Box

The breakout box (HD-41198) will *speedily* diagnose and analyze the integrity of the increasingly complicated wire harness and connections without use of the *laborious* traditional sharp pointed probes that stick into the wires to get readings.

It is also used with a DVOM/Fluke 78 Multimeter.

- Furthermore, the breakout box hooks inline in the system so the bike can actually run during testing.

Simply disconnect the 35-*place connector* by the ECM; place? What does place mean? It is another type of connector that looks like a thin rectangular and flat pin that fits into a slot in the opposite connector. The ECM has the male place connectors and the wire harness disconnected connector is the female place receptacle. The breakout box has two leads to run inline between the wiring harness and the ECM. Consult the service manual for year and model to determine ECM placement for other models like Softails, Heritages, and Dynas.

- The breakout box lead with the 35-place female receptacle plugs into the male place connectors on the ECM.
- Likewise the 35-place male place connectors on the breakout box lead fit into the female place receptacle on the wiring harness.
- The breakout box face has 35-separate attachment holes for the Digital Volt Ohm Meter to plug into that correlates with 35-test functions for various components of the wiring harness. How nifty is that?

Successive Breakout Boxes

As the years pass by, other breakout boxes become specialized and continue on with diagnostic efforts. Some of them are:

1. EFI specific Breakout Box (HD-43876).

2. Radio Breakout Box (HD-44608 and HD-47918).
3. Carburetor specific Breakout Box (HD-42682).

All are used in conjunction with the HD-39978 Fluke 78 Multimeter (DVOM).

In 2011, the Digital Technician II Breakout Box (HD-50390) introduces with new generation digital diagnostics that expands with an additional 130 DTC's (Diagnostic Trouble Codes).

Spark Tester

The Spark Tester (HD-26792) is a very handy tool that tests secondary spark voltage without removal of the spark plug in the engine. The tester confirms that there is an acceptable secondary coil voltage of at least 25,000 volts. It takes a lot of juice to jump the spark plug electrode gap of .038" to .043" to ignite the lean fuel mixture.

Idle Speed Control Actuator Test Lamp

This test lamp (HD-41119-3) will flash to substantiate the appropriate voltage supply is received by the Idle Speed Actuator (ISC). The test lamp plugs directly into the harness connector.

Fuel Pressure Gauge

This gauge (HD-41182) tests both fuel system and injector pressure with the help of another tool called the Fuel Pressure Gauge Adaptor (HD-41182-1). This adaptor allows the actual pressure gauge to attach to the external fuel supply line for diagnosis.

Mity-Vac Vacuum Gauge

The Mity-Vac (HD-23738A) Vacuum Gauge is used to test:

1. MM Barometric Pressure Sensor (BARO).
2. Fuel pressure regulator.

Check Valve Removal and Installation Tool

This tool (HD-41538) is used to take out or re-install the feed and return check valves located in the inside fuel tank gas fittings.

Fuel Injector Removal Tool

The two fuel injectors, each serving a different cylinder, are made from plastic. Therefore the injectors require a protective, precise tool (HD-41320) for removal and installation.

Fuel Tank Plugs

These threaded plugs (HD-41298) have nylon washers to prevent gasoline leakage in order for fuel tank removal from the bike being worked on.

EFI Cylinder Synchronization

Cylinder synchronization detects on later Delphi equipped models by minutely measuring the slowing of crankshaft rotation on compression strokes. As the piston is ascending the cylinder on this cycle or stroke it compresses the air and gas into an increasingly smaller area into the combustion chamber. The resistance to this compression of gases is what causes the crank to slow down very slightly.

The CKP sensor magnetically reads the 30-breaks in the rotating left flywheel thus measuring the rotational slowdown. If possible to observe the rotating crank, the human eye would not distinguish any slowing in movement caused by the increasing compression of gases. Computerization easily reads this infinitesimal change in rotational speed to accurately gauge when to initiate spark.

This is a great improvement over previous electronic ignitions that did not have the luxury of sensors sending precise information thousands of times per second. Computers can diagnose and sometimes fix their own malfunctions. We are now in the age of self-tuning ignitions. The aftermarket has developed them already and Harley surely will increasingly incorporate this function in future years. S&S was the first to do this on a mass scale with their proprietary intelligent spark technology for carbureted models.

EPA Perfection: Stoichiometric Air Fuel Mixture

Two relatively new phenomena relate to punishing demands for an air-cooled engine by the

Environmental Protection Agency. They are Stoichiometric air fuel ratios and closed loop electronic fuel injection. I suppose the acronymists will designate OLEFI and CLEFI to represent open loop and closed loop EFI. Stoichiometric AFR along with closed loop EFI becomes standard on 2006 TC88 Dynas and all Harley-Davidsons from 2007-to-present.

Stoichiometric Air Fuel Mixture

How does someone come up with a name like Stoichiometric? The word is intimidating never mind bizarre. Well, I assumed the fellow that figured all this out in the distant past somewhere lent his name to the concept. As it turns out, *stoichio* derives from the Greek word stoikheion, which roughly translates into *element.* The metric part of Stoichiometric sounds very familiar and identifiable as a classification of measurement. Therefore, Stoichiometric roughly translated means measure element. It follows that the Stoichiometric Ratio of the element(s) in air relative to gasoline is 14.7:1.

Stoichiometry is no fly-by-night theoretical mumble-jumbo as it rests upon three incontrovertible laws of physics:

1. The *Law of Conservation of Mass.*
2. The *Law of Definite Proportions* also known as the *Law of Constant Composition.*
3. The *Law of Multiple Proportions.*

Mercifully, I will spare the reader from further discussion. Everything in the engine management system including the sensors and electronic fuel injection revolves around this Stoichiometric number of 14.7 parts air per one part fuel (gas).

The Stoichiometric Ratio is the optimum air-fuel-ratio where all the available oxygen in the air combines with all the available fuel for burning in the combustion chamber. Stoichiometric AFR is different for various fuels; Gasoline is 14.7; diesel is 14.6; Methanol is 6.4 while ethanol is 9.0. Hence, the reader can now discern how the lower ratios for ethanol and methanol will confuse the ECM that is programmed for 14.7:1 Stoichiometric AFR. Predecessor engines to the Twin Cam ran richer below today's closed loop EFI mandated Stoichiometric AFR.

How does such a lean mixture of fuel burn? Heat is the short answer. Cylinder head design and mating piston dome shape assist mightily but a hotter spark to ignite the thinned out mixture is also necessary. The hotter spark generates from a higher voltage coil within the sophisticated engine management system. Gasoline cools but there is not much in a Stoichiometric mixture.

Lambda

The reader may run across the term Lambda, which is the actual air fuel ratio divided by the Stoichiometric Ratio for that particular fuel.

Lambda = actual AFR ÷ Stoichiometric AFR

Example: if the actual air fuel ratio is 14.7:1.

Lambda = 14.7 ÷ 14.7
Lambda = 1

Therefore, if Lambda is one (1), then the AFR is equal to Stoichiometric. A rich running engine that by definition has an AFR ratio less than Stoichiometric has Lambda less than one. Conversely, a lean running engine that by definition has an AFR ratio greater than Stoichiometric has a Lambda greater than one.

Maximum HP and torque occurs with a Lambda slightly less than one, which translates Stoichiometric under 14.7 parts air to one part fuel, which is no surprise.

ECM Fuel and Linking Ignition Tables are Fixed

Once a stock component part replaces with another like an upgraded exhaust or longer duration-high lift cams, these changes will disturb the factory-installed air/fuel calibration settings that closely link with ignition tables in the electronic control module. In order for a Harley to run properly with a performance change or changes, *adjustments* are necessary to give the ECM obligatory instructions of how much fuel is required.

This is not so simple. Carburetors require mechanical jetting changes. EFI needs electronic adjustments fed into the ECM or to modify signals after they leave the ECM.

The majority of aftermarket ECM modification systems to alter fuel settings are limited to specific changes without further adjustment. They cannot adjust to new components on their own. Sometimes, this will be injurious to the engine if a lean condition develops. Other times the fuel will become too rich and wasteful. It is possible to *rewrite* the stock ECM calibration tables but hardly practical. Most aftermarket units allow a choice of settings or modified tables for specific changes but they need adjustment every time if making another modification.

The automotive industry has been using closed loop EFI forever, preferring it over open loop EFI. Harley-Davidson finally made the switch over to closed loop operational fuel control in 2006 with the Dyna series. It carries over into the full 2007 line-up *including Sportsters.* The reason is the addition of one of the now more important sensors, the O2 or oxygen sensor. This sensor monitors oxygen content in the exhaust stream out the exhaust system. It is real time monitoring and diagnosis of the air-fuel-ratio's efficiency. Now the fuel delivery can correct automatically to the Factory calibration tables basing on EPA dictates.

Self-tuning ignitions like the Terminal Velocity can now recalibrate over *many-times per second* to adjust to not only any changes the rider may make like an air cleaner but to constantly changing load conditions that occur while riding like adding a passenger or trailer, going up hills, going down hills, accelerating, decelerating or simply cruising. The ignition no longer cares as it simply reads the exhaust stream, analyzes the parts-per-million oxygen content, and delivers constant information in milliseconds to the ECM. The aftermarket ignition will make a decision, again in milliseconds to determine fuel requirements instantly. It will also compensate for altitude changes, lowering fuel as elevation increases because of less available air, and increasing fuel as elevation approaches sea level for the same reason of now more air.

Oxygen Sensors

We need some more gas both for cooling the combustion chamber as well as power.

Harley-Davidson uses *narrow band* oxygen sensors that work well in both stock and most performance applications. The exception is with supercharging and turbocharging applications, two examples of forced induction, where wideband oxygen sensors are necessary to deal with higher *boosts* and rapidly changing rpm levels. Forced induction compresses air above atmospheric pressure without a vacuum necessary for natural aspiration thus increasing the intake air-charge. Compression forces more air into the engine, providing a *boost.* With the additional oxygen in the boost, more fuel can inject into the charge, and the power of the engine increases substantially and almost immediately. Lambda AFR can change too fast for narrow band sensors to respond adequately, perhaps leading to engine damage. This is why faster reacting-wideband O_2 sensors are a good idea in these instances. Lower boosts of 6-lbs to 10-lbs can still use the narrow band O_2 sensors without dangerous spikes in air leanness.

Closed Loop Electronic Fuel Injection

A closed loop EFI requires oxygen sensor(s) to feed exhaust composition Lambda to the electronic control module. Closed loop EFI functions at Stoichiometric air-fuel-ratio of 14.7:1. Closed loop needs a full circle to reach its mandated AFR. The full circle ends with the ECM determining *pulse width* of the fuel injectors.

The engine goes through its continuous cycles until completing the exhaust cycle. The O_2 sensors measure Lambda and send a signal back to the ECM. The ECM will increase, or more likely in the real world decrease fuel injector pulse width to reach a Lambda of one (1), which is equivalent to Stoichiometric AFR of 14.7:1.

Closed loop EFI functions in cruising situations where fuel requirements lend toward a regulated Stoichiometric 14.7:1 AFR as well as hot idle. Open loop functions for accelerating and cold idling particularly during engine warming after start-up.

I examine Stoichiometric AFR and Lambda in much greater detail in Volume II: Performancing the Twin Cam.

Open Loop EFI

It is unlikely that open loop EFI will reach an AFR of 14.7:1. However, the probability is a richer condition of around 12.0:1 AFR with a Lambda of less than one (12.0:1 ÷ 14.7:1 = .816 Lambda), will exist with open loop. An air fuel ratio of 12.0:1 is the H-D engine default rich idle mixture.

When the computer (ECM), decides the engine has warmed sufficiently it will put the idle into closed loop and seek a 14.7:1 air fuel ratio. Blipping the throttle or otherwise taking the engine past 1200 rpm from idle of 1000 + or – 50 rpm will engage the closed loop mode and heat up the engine further.

Open loop EFI is not EPA functional for the cruising air fuel mixture ratios on the newer bikes when closed loop 14.7:1 AFR comes into effect.

Accelerating and rich idling cannot use the lean AFR used in Stoichiometric closed loop EFI because the engine will stall at idle and stumble while accelerating generating even hotter injurious cylinder temperatures. These operating conditions require a richer AFR.

Early CVO Problem is Oil Seepage not a Compression Leak

Some early CVO 110 engines particularly in 2007 and 2008 developed a rear gasket leak that manifested typically anywhere from about 1800 miles on outwards from the rear head oil-return dowel-pin. The problem is one of an oil leak and not a compression leak, which is an odd situation for a head gasket. This is a rear cylinder problem that develops more heat because of air-cooling shrouding from the front cylinder. The cause in my opinion is due to excess heat created by a closed loop EFI system's Stoichiometric air-fuel-ratio on a larger displacement engine. Fixing this will require some component part re-design.

Usually, when a head gasket compromises in any way, a compression leak will follow. Most times, a compression leak will destroy the head gasket integrity from the inside out. I have not heard of any CVO 110 rear-head-gasket leaks developing into a full-blown head gasket although, I think it would develop and happen if left unattended.

All the cases I have heard of began early in the warranty period. In the beginning, the struggling dealers did not have adequate information for correcting the situation or proper parts to accomplish a satisfactory result.

Compression Leaks

A compression leak is a serious mechanical problem that needs addressing immediately. Compression leaks result from a blown head gasket from the combustion chamber into the atmosphere with red-hot gases escaping from the engine. These gases act like a blowtorch and if left unattended, will destroy the aluminum gasket surface of both the head and cylinder creating a progressively larger pathway by melting surrounding metal.

Oil Leak

The rear head-gasket oil leak originates from the return-oil-passage outwards through, above, or below a compromised head gasket. An affected rear head gasket will typically begin to weep an oil mist. The weeping progresses into an actual oil leak with more mileage and then oil dripping down on top of the primary case and the entire back of the rear cylinder and head. This results in baked-on oil residue that will drive any new H-D owner nuts.

The gasket from the return passage inwards remains sealed and contains the cylinder's burning fuel and compression as designed. The Motor Company has upgraded the four-inch bore head gasket from the original 16801-07 to one delineated by part number 16801-07A in an attempt to rectify this leakage situation. This gasket replaces with a graphite one (16801-07B). At the time of writing, the Motor Company was redesigning the gasket once again and there are rumors of a 16801-07C gasket in the works. If true, this means four different gaskets to attack a symptom. The new gaskets have not met with success in alleviating this problem. Please see Chapter XIV: *2009 Model Changes*, section, *CVO 110 Engine* for some Band-Aid H-D responses. Fixing a symptom does not fix the causal factor.

Compounding this heat-related problem is the rear head's head gasket surface warping, which precludes a new gasket fix since the head should be planed or replaced if there is more than .006" warpage. I have now seen and measured .007" to .011" warpage on rear CVO 110 head gasket surfaces but none beyond tolerance on the front head's gasket surface.

Attempting to rectify this situation with gasketing will not work if the problem(s) prove to be a structural design or manufacturing glitch. A now-primitive thicker fibrous gasket may alleviate the symptoms. The earlier Harley-Davidson CVO 110 head gasket uses a Viton O-ring around the oil-return-dowel but the proximity of dowel and cylinder liner lets the O-ring hang onto the cylinder liner that shifts from the main body of the cylinder. I am a big fan of a properly-seating O-ring around the oil passage as it intersects the head and the cylinder. Perhaps the CVO 110-cylinder needs a redesign to allow this simple but effective feature.

Furthermore, the CVO cylinder liner also requires a redesign because it does not tie into the cylinder adequately at the top of the bore like on TC88 and TC96 cylinders.

H-D is using high tech MLS (multi-layer system) three-layer head gaskets, which comprise of three separate layers of stainless steel or aluminum. The MLS gasket's two outer layers are embossed in .001" thick Viton rubber-coated stainless steel. I can see where frustrated mechanics might try sealers as an assist. Never use any sealer whatsoever with these gaskets. The MLS gaskets are corrosion resistant, reduce bore distortion, and withstand extreme cylinder pressures. This may well be the reason why MLS gaskets do not blow from the cylinder outwards in the CVO 110 even with the extreme heat present in the rear cylinder.

However, the MLS gaskets need a very smooth roughness average (RA) gasket surface to function effectively. Warpage of .006" and more is not smooth so will cause these high-tech gaskets to blow. I cannot fault the Motor Company for trying to cure this heating mess with progressively better and superlative gasketing. Even though the gaskets are failing, they are leading edge technology.

The primary cause, of course, is excess heat in the rear cylinder. Lower the heat and the symptoms would disappear. However, this not really an option with EPA dictates. Therefore, superior parts metallurgy and design becomes the answer.

Unfortunately, the rider may contribute to overheating situations.

If Idling, Do Not Touch the Throttle!

Leave an EFI throttle untouched by human hand, as the smallest amount of throttle will lean the engine out as long as the ECM is operating in closed loop high heat mode. EFI functions quite well untouched at idle. The interfering human touch only makes a dire situation attempting to cope as best as possible within its EPA limitations much worse.

If the bike accelerates past 1200 rpm at idle, the engine will stumble under high heat duress. The continuation of the lean 14.7:1 AFR condition can drive engine temperature even higher especially in the air-shrouded rear cylinder.

On super hot days or in stop-and-go traffic or a combination of both, the ECM will sense a potential overheating situation in progress and put the engine into parade duty mode. The ECM will direct the EFI out of closed loop function thus lowering the AFR to an approximate 12.0:1 AFR rich condition. This richer AFR attempts to cool an air-cooled engine that is not getting relief from air circulation.

Cylinder head temperatures can go nuts in this type of situation, much higher sometimes than the acceptable 225^0 F to 230^0 F and my preferable 210^0 F to 215^0 F. Of course, lots of fiberglass, especially the lowers on the FLHT models only exacerbates a bad situation.

Stoichiometric AFR and Fiberglass do not Mix!

Many CVO 110 models are touring models with much fiberglass at the front of the engines compromising maximum cooling air flow over the beleaguered engine. These high temperatures result in two destructive trends:

- The first is engine detonation; I call the great engine destroyer.
- Oil oxidation, particularly the more vulnerable to heat fossil oil starts breaking down via heat.
- A third problem may also raise its ugly head with idle dropping to 950 rpm, which is a lessening of pumped oil supply, particularly to the cylinder crowns and mating piston thrust skirts. This may result in the piston oil-cooling jets squirting only around 90% of oil.

Of course, this situation compounds the others since less oil delivery, once again equates to higher cylinder temperatures. Higher cylinder temperatures may heat-scuff the piston thrust surfaces, fore and aft.

If the reader thinks exhaust bluing was bad in the past that was in the good old *cooler days of richer AFR ratios* where closed loop EFI was only an esoteric term few understood. Therefore, the 2007 and later engines as well as the 2006 Dyna guinea pig introduction model have very hot exhaust systems that must cope with the world of closed loop Stoichiometric AFR ratios.

This is what the EPA demands and makes Harley-Davidson compliant but creates all the heat prostration that leads to the head gasket oil-leak breakdown. The rear cylinder temperature heat, a result of leanness and exacerbated by shrouding from the front cylinder contributes to the heat because of lack of air flow combining with hotter air coming back from cooling the front cylinder. Preignition and resultant detonation contributes much to the rear cylinder problem because of excess heat over the front cylinder. In fact, the Stoichiometric fuel ratio of 14.7:1 goes up to 14.8:1 to 16.0:1 on the rear cylinder due to insufficient cooling from air flow leading to the detonation.

Further exacerbating, the heat situation is the use of a 46mm EFI throttle induction module on the CVO 110, the same size as used on the TC96 and the 2006 TC88 Dyna. A larger induction module is required for the extra cubic inches. This may not be possible because of EPA dictates.

Controlling Stoichiometric Heat

Harley-Davidson Heat Control Assists

The EITMS (engine idle temperature management system), also known, as idle temperature cool down turns off the rear cylinder's fuel injector at hot idle. Why do this when gas is the cooling agent and air causes the villainous heat? Burning gas assisted by maximum air generates the heat from too high air-to-fuel ratios. In this case, the Factory uses air as a cooling agent because there is no ignition in the rear cylinder during engine running.

The 2007 to mid-2008 engine idle temperature management system in simple terms offers a cooling feature for hot idle conditions. This engine calibration procedure is available for all FLHT touring models plus police specific FLHTP, FLHP, and FLHPE motorcycles. It is also obtainable for Dyna and Softail models.

This option is available for all these models free of charge from your H-D dealer. EITMS meets the needs for those that ride in very congested traffic on a regular basis or need to leave their bikes idling as in a police situation. It also assists overheating situations, when the bike returns to idle. The calibration offers limited rear cylinder cooling when cylinder temperatures reach a certain level.

Once EITMS activates, the rear cylinder still functions without fuel. Air still sucks in on the intake stroke, compressed on the compression stroke, decompressed on the power stroke, and exhaled on the exhaust stroke. The air acts to cool the engine rear cylinder while only running on the front cylinder. The potato-potato idle sound will be different since only one cylinder is contributing one potato to the noise rhythm while there is the sound of the whooshing of air from the other. This will also affect the exhaust smell. I mention the above to allay fears that not all is right if not prepared for these EITMS normal symptoms. The EITMS will only function when:

- There is high engine temperature
- The engine is at idle speed.
- The bike is not moving.
- The transmission is in neutral; or if in gear with the clutch lever pulled in thereby disengaging the clutch.
- When all of the above conditions meet, the rear cylinder will stop firing. EITMS will allow supply of fuel to the rear cylinder if:
- Temperature decreases.
- The throttle is increased.
- The bike moves forward.
- The clutch engages.
- Or the bike shifts out of neutral with the clutch engaged.
- Then the rear cylinder and thus the engine will begin running normally.

This free one-time activation and one-time deactivation if the rider finds it unnecessary or simply dislikes the feature is available for the models and years listed above. The 2008 Screamin' Eagle models have the calibration activated from the Factory. The owner can have it deactivated by request at no cost. Quote Service Bulletin M-1191; labor code 8202; customer concern code 9203 and condition code 9110 although referring to M-1191 will do the trick.

In 2009, the FLHT Engine Idle Temperature Management System becomes rider controlled. The EITMS feature located in the stock ECM or electronic control module can turn on-or-off via the throttle grip. Once enabled, the rider can turn off fuel delivery to the rear cylinder *when the bike is idling*. The rear cylinder then becomes an air pump as cooling air introduces and expels with the four engine strokes. Once the throttle turns for acceleration away from idle, the EITMS turns off automatically. The late-2008 and 2009 EITMS calibration cannot be used on early-2008 and previous years touring models.

There are new ECM fuel and ignition calibrations for 2009.

- The Factory has also developed a fan (part # 91550-00C, chrome; 91531-00D, black), that installs on touring FLHT's to lower engine oil tank temperatures a claimed 20 degrees Fahrenheit measured at the oil tank when using the fan. [8]
- Harley includes its Premium 8-core oil cooler on the CVO 110 to assist in combating higher oil temperatures.

I believe that H-D only has a 9.3:1 compression ratio on the 2007 and 2008 CVO 110 to combat higher cylinder temperatures by reducing compression. This is necessary for combating

EPA current and future standards but is a step in the wrong direction for a performance engine. Remarkably, compression reduces on 2009 CVO 110 models to 9.15:1 and 9.2:1 on the Ultra Glide model.

Further Harley-Davidson assists need to be in the redesign department so engine components will not wither in the onslaught of very high AFR fuel ratios.

Aftermarket Heat Control Assists

BAKER Drivetrain (www.bakerdrivetrain.com) now has the +1 Oil Pan that fits 1993-2008 FLT touring models increasing oil capacity a full quart for a reduction in operating temperatures and an increase in engine durability. The website states:

- Reduces engine oil temperature by 10^0 on an 80^0 day.
- The feed and return on a stock pan are located within a 2-inches of each other in the front of the pan. BAKER+1 pan have the feed located in the rear and the return in the front for more compete system circulation.
- Multiple integral aluminum baffles eliminate the stock plastic baffle. [9]

Everything is about temperature because it does not require a rocket scientist to understand that the cure is about less heat. Any method or more correctly methods offering an assist to a cooler operating cylinder are welcome. The oil tank baffles ensure that the hot returning oil circulates thoroughly throughout the oil pan in order to cool more effectively and ensure that all the oil participates in the process.

The 8-core turbulated H-D oil cooler is a great idea for any Twin Cam. It is a stock and very necessary component on the CVO 110. As I said above, its addition to the CVO 110 is an attempt to control cylinder head temperatures in addition to the anemic compression ratios that range between 9.15:1 and 9.3:1. Turbulation mixes the oil for superior heat dissipation. Coolers without turbulation only cool the outside laminar flow of oil, an inefficiency that leaves central lamination oil as hot leaving the cooler as when entering it. However, I feel that only one oil-cooler is not enough. As Bob Wood has taught me, we need more cooling to lower cylinder head temperatures to between 210^0 to 220^0 to control engine detonation, even though literature list 225-degrees as a manageable temperature. [10]

It is not a good idea to run two H-D oil coolers in tandem because of *pressure drop*. Oil restriction causes pressure drop. We do not want to risk starving the engine for any oil whatsoever. I discuss the performance necessary oil coolers, thermostats, turbulation, pressure drop and other factors in Volume II: *Performancing the Twin Cam*: Chapter VI: *Oil Coolers*. Externally, I recommend running two 10-core Jagg oil coolers in tandem on any performance Twin Cam that includes the CVO 110. I have them on my personal performance TC103 bike and the combination works very well. A single 10-core Jagg cooler is sufficient on a stock TC88 or TC96.

Conclusion

The key is to have trust in a very competent mechanic and abide by his or her decisions. If that person cannot explain comprehensive reasons for using a specific part over another, find a different adviser. Patronize this one person consistently. Buy your parts from this person or the shop he or she works for. The reason is that if a problem occurs there is only one person to deal with since only one person has touched your ride. Otherwise the blame game takes over and the consumer may get the short end of the stick.

[1] United States Environmental Protection Agency. *Reformulated Gasoline and Vehicle Performance.* http://www.epa.gov/OMS/rfgvehpf.htm

[2] Harley-Davidson. *1999 Harley-Davidson Service Manual Softail Models Official Factory Manual.* Part No. 99482-99. Section 3, Engine Specifications, Page 3-4.

[3] S&S Cycle, Inc. La Crosse, WI. USA. August 1, 2006. *CLOSED LOOP FUEL INJECTION AND ETHANOL BLENDED FUEL.*

[4] Tim Doherty, Doherty Machine. Email interview July 16, 2007.

[5] Report of the House of Representatives. United States of America. *House Report No. 93-1197, 93rd Congress 2nd Session.*

[6] Harley-Davidson. Service Bulletin M-1005. *COLD WEATHER MOTORCYCLE OPERTION.* November 13, 1990.

[7] Harley-Davidson. Service Bulletin M-1005. *COLD WEATHER MOTORCYCLE OPERTION.* Section *Fuel Additive usage for Cold, Damp Conditions.* November 13, 1990.

[8] Harley-Davidson. *2006 Harley-Davidson Genuine Motor Accessories and Genuine Motor Parts.* Page 442, E.

[9] BAKER Drivetrain. Website, www.bakerdrivetrain.com, page, FLT Transmission.

[10] Wood, Bob. Wood Performance Carburetors. Part of a telephone conversation early 2007.

CHAPTER IX

Synchronizing Ignition and Fuel Delivery

The electronic ignition systems introduced in midyear 1978 forms the basis of the present day engine-management-systems. Certainly, the original electronic ignitions were crude relative to what is standard fare today. Furthermore, they had interesting but frustrating quirky teething problems. Riders of the day were instantly aggravated with these new-fangled concepts that they did not understand nor did they want to. Once again, there was a faithful love affair for tradition born through the Flathead, Knucklehead, Panhead and Shovelhead years and the way it was for their beloved breaker points and condenser ignitions. The introduction of the initially problematic electronic ignition was born from:

1. A realization by Harley-Davidson of coming emissions controls.
2. More importantly, the necessity of developing the more reliable H-D Evolution motorcycle to ensure company survival.

The traditionalists did not realize the multitude of unwanted changes were improvements to save their wonderful dinosaurs from extinction.

A Brief History of Modern Harley-Davidson Ignitions

The modern points (30605-48A) system more correctly called a *breaker point set* in Harleyese has been in use since 1948. However, the previous point's setup went back far beyond 1948. The concept was exactly the same from 1930 to early 1978. The differences lay with basically three mounting system redesigns. The electrical storage component of the system utilizes a condenser (32726-30A) that incredibly saw usage for 48-years from 1930 right up until their demise in early 1978. The point's design changed for the third and last time from a distributor mount to internal timing gear cover relocation in 1970. Late-1978 marked the use of the first electronic ignition on the Shovelhead readying for the Evolution introduction.

1. The first electronic ignition used on Big Twins from late 1978 to 1979 known as the V-Fire I was a hybrid utilizing a mechanical advance mechanism with a solid state ignition module.
2. A second improvement occurred between 1980 and 1983 with the Shovelhead V-Fire II ignition that incorporated both a solid-state advance/retard component and a separate remote ignition module connected via wiring to the sensor and rotor components inside a compartment in the timing cover.

3. The Evolution V-Fire III was a huge advancement because it was solid state with much the same configuration as the V-Fire II but with the first use of a sensor in a Harley-Davidson. This began an ignition management system with a separately mounted VOES (Vacuum Operated Electrical Switch) that measures and relays manifold pressure to the ECM. Thus, the marriage between fuel delivery and ignition began.

Mechanical Points/Condenser Ignition: 1970 to Early 1978

Although, points/condenser ignitions were never used on production Evolution or Twin Cam motorcycles, many Evolutions and some Twin Cams were converted back to this mechanical ignition system.

Before starting, I of course, have an opinion on this retro conversion. Traditionalists, which were pretty much every Harley rider of the day, hated the advent of non-adjustable electronic ignitions. The fact that there were early teething problems for the mysterious new non-rebuildable components did not help acceptance at all. The early Evolution riders just wanted peace of mind. They knew and understood points and condensers. They could repair or perform maintenance on them in their sleep. What they failed to grasp was that there would virtually be no repairs or maintenance required once H-D straightened out the early electronic problems.

I have also converted Twin Cam engines to a point's ignition system, particularly in the early years. I have not been asked to do this for probably seven years now so I guess all the traditionalists have given up or do not realize it is possible.

I understand all this because I too am a traditionalist. The difference is that I understand that change is necessary and inevitable so I have to adapt or fall by the wayside.

The government expected emissions controls to be met. Points do not have that capability. Therefore H-D would not exist today if it did not adapt to new regulations.

- The new consumer, so necessary for the survival of this venerable company back in the 1980's would not tolerate a high maintenance, repair prone motorcycle. The lack of new H-D riders would also have spelled Harley-Davidson's demise.

However, from a mechanical and efficiency perspective there is no reason to retrofit back to this dinosaur ignition system. By the time the Evolution arrived in 1984, H-D had perfected the electronic ignition with the V-Fire III. This ignition gave:

1. Better performance as in a faster motorcycle.
2. Reliability.
3. Improved gas mileage.
4. A reduction in harmful environmental emissions.

In short, the V-Fire III electronic ignition along with many other mechanical upgrades ensured the survival of Harley-Davidson on a faster and more reliable motorcycle. I know that all of these arguments will not convince some riders so for their benefit I include the following information for their beloved point's ignitions.

Point's ignitions have moving parts while electronic ones are solid state with no moving parts. The electronic successors are virtually non-adjustable and without rebuild possibilities. The tinkering Harley riders of the day were not impressed.

The latest points (32661-70) ignition is problematic in the same ways as their predecessors from:

- Burning and pitting contact faces from maladjustment or other lack of maintenance.
- Oil on the contact faces.
- Moisture on the contact faces from rain, bike washing, or condensation buildups.
- However, they are easily maintained and/or repaired.

If the condenser went south on the side of the road, a variety of farm tractor or car condensers easily replaced the defunct unit. These rebuild/maintenance features found enduring love with the self-sufficient riders of the day.

The breaker-points and condenser ignition system has two circuits; the primary ignition circuit and the secondary ignition circuit.

The Primary Ignition Circuit

Briefly, the primary circuit consists of:

1. Battery (12V).
2. Ignition switch.
3. Primary coil windings.
4. Breaker points.
5. Condenser.
6. Related wiring.

The Secondary Ignition Circuit

The secondary circuit consists of:

1. Secondary coil windings.
2. Spark plug wires.
3. Spark plugs.
4. Related wiring.

For a comprehensive discussion on this ignition system throughout H-D history, please see Volume III: *The Evolution: 1984 to 2000*; Volume VI: *The Shovelhead: 1966 to 1985*, and Volume VII: *Panheads, Knuckleheads, and Flatheads: 1929 to 1973.*

The First Electronic Ignition: 1978 to Early 1979

The V-Fire I in mechanic-speak is a breakerless-inductive-discharge ignition system with two circuits. I will delve into this ignition system in greater detail in Volume VI: *The Shovelhead: 1966 to 1985.* However, I will spend some time on this even though it is Shovelhead ignition and not an Evolution or Twin Cam one. The reason is that this is the first electronic ignition that the V-Fire III ignition feeds off and improves. The V-Fire II ignition is virtually the same as the initial Evolution V-Fire III except for tying in fuel delivery with the advance-retard ignition timing solid state spark delivery.

The Primary Ignition Circuit

Briefly, the primary circuit consists of:

1. Battery (12V).
2. Ignition switch.

3. Primary coil windings.
4. Ignition timer.
5. Related wiring.

The Secondary Ignition Circuit

The secondary circuit consists of:

1. Secondary coil windings.
2. Spark plug wires.
3. Spark plugs.
4. Related wiring.

The Gear case Ignition Timer

The ignition timer in the gear case cover consists of:

1. Trigger rotor.
2. Sensor.
3. Ignition control module.
4. Advance-retard weight system.

Therefore, the V-Fire I still depends on a mechanical advance-retard for computerized solid state spark delivery.

The ignition timer does two things:

1. It opens and closes a low voltage (12 volts) circuit between the battery and the (ignition) primary coil windings. The secondary coil windings produce high voltage in excess of 20,000 volts and discharge this through the coil wires to the spark plugs.
2. The ignition timer determines when the high voltage discharge sparks the plugs beginning combustion at the most opportune time.

The Ignition Trigger Rotor (Ignition Cam)

The trigger rotor (32602-78):

1. Sits on a shaft and plate (32629-70) inside the timing cover.
2. The shaft and plate affixes to the end of the engine camshaft and rotates with the shaft.
3. The trigger rotor sits over the center shaft of the plate, thus rotating with the plate and camshaft.
4. The trigger rotor has slots at its base that mate with the advance-retard weights of the timer system. Centrifugal force created by the engine running and thus rotating the camshaft moves the weights out, thereby rotating the trigger rotor slightly into the advanced position. When rotational force lessens as the bike slows down, the trigger rotor and weights move back to a retarded position.

Advance means the spark plug fires earlier because the pistons are moving faster and the same amount of time is required to burn the air-fuel mixture. Retard means the spark plug fires later because of slower piston speeds again needing the same amount of time for the burning process.

- The trigger rotor has two lobes that are higher than the base rotor, one for firing the spark plug in each cylinder. The narrow lobe fires the front cylinder plug while the wider lobe fires the rear.

- If the reader is confused, the pictures and descriptions in Volume III: *The Evolution: 1984 to 2000* will elucidate.

Adjustability

I stated earlier that electronic ignitions are fixed with no adjustability component. This is not quite true since the V-Fire I electronic ignition utilized a solid-state ignition module assembly (32598-78) in conjunction with a limited adjustable timer plate and a weight and rotor assembly (32505-78A). I think the A-suffix indicates the addition of a Teflon coating since these units wear out fast.

The V-Fire I worked in conjunction with the weight and rotor assembly that I more descriptively refer to as an automatic, mechanical advance/retard centrifugal force springs and weights. This centrifugal weight system sat on and bolted to the end of the camshaft in the timing case gear cover also known as a *nosecone* (25216-70, 25216-73) with an overly long and skinny 10-32 x 2" bolt (H-D 3570). This irritating accident-waiting-to-happen carried over from the 1970 to 1978 points ignition mounting system. Harley riders and mechanics alike were constantly breaking this HD-3570 bolt by screwing it in too hard, which a baby could easily do. Many times, it also broke while attempting to remove it because of thread corrosion. If the circuit breaker assembly was not installed perfectly square, its weight compounded by rotational force would certainly snap this pitiful bolt with ease.

The Ignition Sensor

The ignition sensor attaches by wiring and is part of the ignition control module although it screws (H-D 2554) to the timer plate via a 4-40 x ⅝ Pozidriv fil. Hd. (Pozidrive fillister head) screw, which is similar to a star configuration screw head:

1. It consists of wiring, wound on a core.
2. It sits on the timer plate in close proximity (.004" to .006") to the trigger rotor, which sticks through the middle.
3. The sensor is fixed while the trigger rotor rotates.

Sensor Air Gap

To adjust this gap known as an *air gap*, rotate the engine with spark plugs removed for ease of movement until the wide lobe of the trigger rotor is adjacent to and centered on the sensor. Check gap with a narrow feeler gauge. If not between .004" to .006", loosen the sensor hold down screw(s) since some units have one screw and others two and move the sensor as required to achieve the specified air gap. Repeat this procedure for the front cylinder's narrow lobe on the trigger rotor. The gap for both the wide and narrow trigger rotor lobes should be as equal as possible, which many times involves compromise settings.

The Ignition Control Module

The ignition control module is solid state with no moving components. It contains all the non-moving parts in the ignition system. It includes:

1. An integrated circuit chip comprising of:
    a) Oscillator circuit.
    b) Demodulator circuit.
    c) Demodulator transistor.

The module is protected from vibration, dirt, oil, and water by a silicone coating.

The V-Fire I Ignition Coil

The V-Fire I's 12-volt coil is the same as the earlier point's ignition coil, which is another irritation with this problematic electronic ignition. This electronic ignition uses a point's ignition coil, which does not generate sufficient voltage to the spark plugs on an electronic system. It is also dual fire, which means it fires both spark plugs twice during the four engine cycles, once on the compression stroke and secondly a wasted spark on the exhaust stroke. Single fire coils fire the plugs once on the compression stroke thereby eliminating the wasted spark. All Twin Cams use single fire beginning after the Evolution in 1999.

The V-Fire I coil is a *pulse type transformer*. The coil takes the relatively low battery voltage of 12 volts in *pulse* form thanks to the sensor and rotor creating Hall voltage. It then *transforms* (steps up) the low battery voltage into the high voltage required to jump the spark plug electrode thus igniting the air-fuel mixture.

If I cut an ignition coil apart, there would be primary and secondary wire windings surrounding a laminated iron core. These parts are then sealed with waterproof insulation. The main difference between an electronic coil and corresponding points one is the number of windings around the core. Therefore, points type and V-Fire I ignition coils are different from 1980 and later electronic coils and are not interchangeable. Later coils are more powerful and will burn out the points and overwhelm the condenser. Early coils do not put out enough juice to effectively bridge the large gap on electronic spark plugs. Early electronic coils are marked ELECTRONIC or ELECTRONIC ADVANCE to distinguish them from identical looking rounded points/V-Fire I coils. As the years progress the shape of the electronic coil changes from a rounded appearance to a squared-off one for easy coil identification. Coil wires are also different as are the spark plugs because they are necessarily radio frequency (RFI) protected to prevent external interference.

Ignition and Fuel Delivery are Separate

This V-Fire I electronic ignition with mechanical advance and fuel delivery are completely separate functions on bikes utilizing this problematic system from late 1978 and through 1979.

For a comprehensive discussion with pictures on this ignition system, please see Volume III: *The Evolution: 1984 to 2000* and Volume VI: *The Shovelhead: 1966 to 1985.*

V-Fire II Electronic Ignition: 1980 to 1983

Mercifully, H-D discontinued the inefficient, high-wear, and high-maintenance automatic, mechanical advance/retard centrifugal force springs and weights with the 1980 to 1983 V-Fire II electronic ignition. It replaces with a computerized ignition timer that forms part of the first Harley-Davidson complete solid-state ignition control module. The V-Fire II is the basis for the Evolution V-Fire III ignition that begins the era of engine management systems coordinating fuel delivery with ignition via information sent by input sensors.

The V-Fire II is like the V-Fire I in that it is a breakerless-inductive-discharge ignition system with two circuits, the primary and secondary circuits.

The Primary Ignition Circuit

Briefly, the primary circuit consists of:

1. Battery (12V).
2. Ignition switch.

3. Primary coil windings.
4. Computerized Ignition timer.
5. Related wiring.

The Secondary Ignition Circuit

The secondary circuit consists of:

1. Secondary coil windings.
2. RFI spark plug wires.
3. RFI spark plugs.
4. Related wiring.

The V-Fire II Ignition System Components

The computerized ignition system consists of three main parts:

1. Rotor.
2. Sensor plate.
3. Ignition control module (ICM for ignition control module or ECM for electronic control module), which is a computer microprocessor module. Both terms as well as ICU (ignition control unit) all refer to the same module. ECM is the most commonly used term.

The rotor and the sensor plate locate inside the nosecone while the ICU, ICM or ECM, take your pick, usually locates externally on the front of the frame down tubes below the charging system's regulator. The reader may also find it under the FLT/FLHT fairing in a couple of places; under the FXR right side cover or under the seat itself. Later years saw the development of more ECM locations. To access the sensor plate and the rotor it is necessary to remove the nosecone (25258-80A) gear cover's front timer cover (32504-80) that is purposely affixed with two non-removable 5-32 x ⅜" long with a 5/16" diameter head pop rivets (H-D 8699). These must be drilled out to access the timing components inside the nosecone.

Manuals advise to replace these rivets after service. If doing so, utilize the HD-8699 rivets instead of other types. This is important since the HD-8699 rivets do not have a piece that will fall off into the timing cover after installation. Metallic pieces of other types of rivets will wreak havoc with the sensor Hall effect magnet. As far as I am concerned, there are two reasons for preventing the rider into gaining access to the ignition components.

1. Maintain stock ignition timing for EPA and CARB emissions controls.
2. Discouraging riders from working on their own bikes thus providing their H-D service departments with more work.

I never replace the rivets and install easily removable 8-32 screws that thread into the existing ignition timer cover studs (32601-80) from 1980 to early 1982. Late 1982 to 1983 Shovelheads use 10-24 screws that fit into the updated ignition timer cover studs (32606-82).

The V-Fire II Electronic (Ignition) Control Module

The Electronic Ignition Control Module performs two functions:

1. It opens and closes a low voltage (12 volts) circuit between the battery and the (ignition) primary coil windings. The secondary coil windings produce high voltage of about 20,000 volts to 30,000 volts and discharge this through the coil wires to the spark plugs.

2. It also computes when the high voltage discharge sparks the plugs beginning combustion at the most opportune time. In other words the computer calculates ignition advance/retard settings.

Voltage increases with the V-Fire II because it is required to efficiently jump the wider spark plug gap of .038" to .043" and ignite a leaner air-to-fuel mixture.

Again, the difference in piston speeds in the starting procedure, idling, cruising, acceleration, and bike slowing down to a stop requires that spark occurs in time during the compression stroke for optimal and complete combustion to occur on the power stroke in order to drive the pistons down.

The ECM will operate down to as low as 5.7 volts DC (direct current). The module offers protection against:

1. Damage to jump-starts. This is a biggie. Imagine the damage to the ignition system if not afforded this security?
2. Constant reverse voltage protection.
3. Transitory voltage.

The Microprocessor (ECM) Calculates Dwell Time

Dwell time is the amount of time current runs through the primary circuit of the ignition coil. Therefore, in a point's ignition system, dwell is the amount of time the contact points are closed. Current is only sent to the spark plug when the points open. So if the dwell time is too short, the current in the primary windings of the ignition coil will not been able to build up far enough. This will provide a disappointing result of insufficient magnetic energy stored in the coil to generate a hot spark to cross each spark plugs electrode.

The dwell time or period on an engine with an electronic ignition like the V-Fire II and V-Fire III is controlled by the current within the electronic (ignition) control module. Therefore, the ECM calculates sufficient dwell time for the coil's primary circuit to build up necessary current to eventually jump the spark plug gap; eventually measures in milliseconds.

Dwell time depends on engine rpm and expands as engine speed increases to compensate for the shorter time period. This can overwhelm the charging system's capacity to replenish the battery thus causing the battery to drain. However, the ECM microprocessor comes to the compromise rescue and programs the dwell period to provide sufficient current to the primary windings of the ignition coil depending on engine speed *without draining the battery.*

The V-Fire II Ignition Coil

The 12-volt V-Fire II coil is dual fire, which means it fires both spark plugs twice during the four engine cycles, once on the compression stroke and secondly a wasted spark on the exhaust stroke.

The V-Fire II coil is a *pulse type transformer*. The coil takes the relatively low battery voltage of 12 volts in *pulse* form thanks to the sensor and rotor creating Hall voltage. It then *transforms* (steps up) the low battery voltage (12 volts) into the high voltage required to jump the spark plug electrode thus igniting the air-fuel mixture.

Early V-Fire II electronic coils are marked ELECTRONIC or ELECTRONIC ADVANCE to distinguish them from identical looking points and V-Fire I coils. As the years progress the shape of the electronic coil changes for easy coil identification. Coil wires are also different as are the spark plugs because they are necessarily radio frequency (RFI) protected to prevent external interference.

V-Fire II Ignition *Hall effect* Trigger Rotor

New for the V-Fire II is the ignition rotor that locates in the gear case cover bolted to the end of the camshaft by a short and skinny 10-32 x ½" bolt (H-D 2611B). This short bolt is still fragile but it holds the thin sheet metal inverted ignition rotor cup with ease. Breakage is no longer a problem. The ignition trigger rotor consists of:

1. An inverted cup with two slots cut out of its external edge.
2. It rotates so that the slot cutouts interfere with and break a magnetic field created by a Hall-effect device.

Hall effect devices are used right up to current Twin Cam Harley-Davidson's in many places and situations including the TGS throttle grip sensor that replaces manual throttle and idle cables in 2009.

For thirty years I did not have a clue why a Hall effect device was named as it was. A fellow named Edwin Hall discovered the Hall effect and its resultant Hall voltage in 1879. The principle describes the difference across an electrical conductor crossway to an electrical current in the conductor relative to a magnetic field perpendicular to this current. The difference is called Hall voltage. Man, let me try this one more time by putting it another way. I'm almost sorry that I researched a Hall effect, as ignorance may have been bliss. Hall voltage creates across a current-carrying metal strip when placing the metal strip perpendicular in a magnetic field. I'm going to leave it at that.

The Hall effect creates when the inverted and rotating trigger rotor cup (32401-80) moves around the fixed sensor assembly (32400-80). The slots in the external edge of the trigger rotor break the magnetic field created by the Hall effect device mounted on the sensor plate. The Hall voltage or signal from the Hall effect device corresponds to the timing information from the precisely cut cup slots.

Hall Effect Advance and Retard Settings

Simply, the Hall effect is all about ignition spark timing during the compression stroke leading into the power stroke.

1. Starting ignition spark timing is near TDC where the piston is almost top dead center at the end of the compression stroke just before the beginning of the power stroke.
2. Running spark ignition advance will vary between the retard setting at 3-degrees before top dead center (BTDC) and the full advance setting at 35-degrees BTDC.

Ignition and Fuel Delivery are Separate

This V-Fire II electronic ignition with solid state advance and fuel delivery are completely separate functions on bikes utilizing this improving system from late 1980 and through 1983.

For a comprehensive discussion with pictures on this ignition system, please see Volume III: *The Evolution: 1984 to 2000* and Volume VI: *The Shovelhead: 1966 to 1985.*

Ignition Timing Chart 1970-to-present Shovel-Evolution-Twin Cam

Please check your manual. There may be a different specification than listed here. All manuals do not agree or some retro back and override a previous specification.

Year	Variance	Retard (Starting) 1000-1050 rpm	Fast Idle 1050-1500 rpm	Advance 1050-2800 rpm †
1970-Early 1978 Points [1]	5°-35° BTDC	5° BTDC	NA	35° BTDC
L-1978-1979 V-Fire I [2]	3°-35° BTDC	3° BTDC	NA	35° BTDC
1980-1983 V-Fire II [3]	3°-35° BTDC	3° BTDC	NA	35° BTDC
E-1984 FXST	5°-50° BTDC	5° BTDC	35° BTDC	50° BTDC
L-1984-1994 FXST	0° TDC-35° BTDC	5° TDC	35° BTDC	35° BTDC
1995-1999 FXST	0° TDC-42.5° BTDC	0° TDC	20° BTDC	42.5° BTDC
1991-1994 FXD	0° TDC-35° BTDC	5° TDC	35° BTDC	35° BTDC
1995-1996 FXD	0° TDC-20° BTDC	0° TDC	20° BTDC	20° BTDC
1997-1998 FXD [5]	0°-42.5° BTDC	0° TDC	20° BTDC	42.5° BTDC
1984 FLT/FXR	5°-50° BTDC	5° BTDC	35° BTDC	50° BTDC
1985-1994 FLT/FXR	0° TDC-35° BTDC	0° TDC	5° BTDC	35° BTDC
1995-1998 FLT	0° TDC-42.5° BTDC	0° TDC	20° BTDC	42.5° BTDC
1999-2008 FLT	0°-50° BTDC	0° TDC	20°-30° BTDC	50° BTDC
2009 FLT	-4° ATDC-50° BTDC	12°-24° BTDC	varies	45° BTDC
Dyna	0°-50° BTDC	00 TDC	varies	50° BTDC
Softail	0°-50° BTDC	00 TDC	varies	50° BTDC

Consult manual to confirm specific year and model ignition settings. As the years go by, manuals are less likely to give this specification; perhaps because the ignition is non-adjustable and fixed from the Factory. It is possible to sometimes find reference to fixed ignition setting specifications in the specialized workshop manuals called Electrical Diagnostic Manual's such as *2005 HARLEY-DAVIDSON® ELECTRICAL DIAGNOSTIC MANUAL,* part number 99496-05.

† The full BTDC advance degrees of flywheel rotation may be greater than the set timing advance figure. Advance Timing RPM for adjustment is the rpm that actual ignition timing is set to observe the front cylinder timing mark in the timing plug hole. The advance timing figures shown here may or may not correspond to the set timing figures. Confusing? I know.

[1] 1970 to Early 1978 Points and Late 1978 to 1979 V-Fire I electronic ignitions use the primitive, high maintenance, and mechanical centrifugal-automatic-advance-weight and spring system to advance and retard ignition timing. The closed breaker-points provide the initial low voltage to the primary coil windings. The opening contacts and condenser provide the collapsing field to step up the voltage in the secondary coil windings and spark the plug's electrode. Ignition and fuel delivery are separate functions.

[2] The late-1978 to 1979 electronic ignition with mechanical-centrifugal-advance sends an electrical signal to the ignition sensor, which creates a field around the sensor. A trigger rotor rotates inside the sensor. The individual passing lobes for front and rear cylinders will reduce the strength of the oscillating circuit electrical signal. The ignition module's demodulator detects this reduced sensor signal for each passing lobe. The demodulator transistor turns off the current pulse into the coil's primary circuit. The mumbo-jumbo is not what is important here but the fact a pulse is created and then collapsed for the coil to begin the transformer or

step-up voltage to bridge the electrode gap on the end of the spark plug to ignite the air-fuel mixture and begin combustion. Ignition and fuel delivery remain separate functions.

[3] The 1980 to 1983 V-Fire II electronic ignitions is true solid state without moving parts including the advance-retard timing component. A Hall effect magnetic sensor provides the initial pulse to the primary coil windings. The ECM calculates this dwell time. It then collapses or stops the pulse feed to the primary coil windings to institute the step-up voltage process in the coil's secondary windings. Ignition and fuel delivery still remain separate functions.

[4] Specifications are for Evolution except FXST. The 1984 to 1999 V^2 V-Fire III electronic ignitions is also true solid state without moving parts including the advance-retard timing component. A Hall effect magnetic sensor provides the initial pulse to the primary coil windings while the microprocessor ECM calculates the length of time or dwell for this pulse. The V-Fire III is very reliable. It is the basis for the modern and progressive *engine management system* that coordinates fuel delivery with ignition spark timing. The first sensor arrives in 1984 with the VOES (vacuum operated electrical switch) that monitors vacuum inside the carburetor manifold. The VOES sends this information via electrical signal to the ECM, which coordinates the first ignition spark delivery with engine load. Engine load or how hard the engine is working (idle, cruise, or acceleration) is indicated by vacuum in the manifold. This also specifies the level of fuel delivery.

[5] Circa 1996, H-D introduced the first carbureted sensor other than the VOES switch. The Cam Position Sensor (CMP) locates on the sensor plate inside the nosecone gear cover in conjunction with a second sensor the Vehicle Attitude Sensor (VAS). Ignition spark timing now improves with more accuracy because the CMP signals the ECM exactly where the pistons are on their respective engine cycles or strokes. The reader might ask how the ECM would know piston position from cam rotation. Well, every moving part of consequence in the engine times to each other. The flywheels rotate, which moves the pistons up and down in their cylinders. The flywheel assembly's integral pinion shaft times to its pinion drive gear. This pinion gear times to the camshaft drive gear and to the return oil pump's breather gear. The cam lobes time to the camshaft drive gear. The cam lobes open and close the valves on their respective cycles or strokes; intake, compression, power, and exhaust. Therefore, cam position also reverts back to flywheel assembly piston position. The ECM knows exactly where the pistons are *and how fast they are moving.* Therefore, the ECM can time when to spark the plugs for ignition to derive the most complete combustion possible for heat expansion to push (pressure) the pistons down on their power stroke. The VAS sensor that does not get much mention in manuals will turn ignition off if the bike tilts more than 80-degrees as a safety feature that also preserves the engine in case of a fall.

V-Fire III Electronic Ignition: Evolution 1984 to 2000

There is no clear delineation when the V-Fire III ignition formerly ends but the beginning of the Twin Cam era in 1999 or 2000 depending on model is as good a place as any.

Ignitions Coordinating with Carburetion

The V-Fire II is the basis for the Evolution V-Fire III ignition that begins the era of engine management systems coordinating fuel delivery with ignition via information sent by input sensors.

The V-Fire III like the V-Fire II is a breakerless-inductive-discharge ignition system with two circuits, the primary and secondary circuits.

The Primary Ignition Circuit

Briefly, the primary circuit consists of:

1. Battery (12V).
2. Ignition switch.
3. Primary coil windings.
4. Computerized Ignition timer.
5. Related wiring.

The Secondary Ignition Circuit

The secondary circuit consists of:

1. Secondary coil windings.
2. RFI spark plug wires.
3. RFI spark plugs.
4. Related wiring.

The V-Fire III Ignition System Components

The computerized ignition system consists of three main parts:

1. Rotor.
2. Sensor plate.
3. Electronic control module (ECM), which is a computer microprocessor module.
    - VOES (vacuum operated electrical switch) feeds the ECM information regarding intake manifold pressure (vacuum), which is an indicator of engine load or how hard it is working.

Accessing the Sensor

The rotor and the sensor plate locate inside the nosecone gear cover. To access the sensor plate and the rotor it is necessary to remove the nosecone (25258-80A, 25256-93A etc.) gear cover's front timer cover (32504-80 etc.) that is purposely affixed with two non-removable 5-32 x ⅜" long with a $^{5}/_{16}$" diameter head pop rivets (H-D 8699). These must be drilled out to access the timing components inside the nosecone.

Manuals advise to replace these rivets after service. If doing so, utilize the H-D-8699 Harley supplied rivets instead of another type. The HD-8699 rivets do not have a piece that will fall off into the timing cover after installation that will wreak havoc with the sensor Hall effect magnet. I always discard the rivet installation procedure and install easily removable 10-24 screws that fit into the ignition timer cover studs (32606-82) on 1984 to 2000 Evolutions

The V-Fire III Electronic (Ignition) Control Module

The Electronic Ignition Control Module performs two functions:

1. It opens and closes a low voltage (12 volts) circuit between the battery and the (ignition) primary coil windings. The secondary coil windings produce high voltage of about 20,000 to 30,000 volts and discharge this through the coil wires to the spark plugs.
2. It also computes when the high voltage discharge sparks the plugs beginning combustion at the most opportune time. In other words the computer calculates ignition advance/retard timing settings.

Voltage increases with the V-Fire II and V-Fire III because they are required to efficiently jump the wider spark plug gap of .038" to .043" and ignite a leaner air-to-fuel mixture.

Again, the difference in piston speeds in the starting procedure, idling, cruising, acceleration, and bike slowing down to a stop requires that spark occurs in time during the compression stroke for optimal and complete combustion to occur in order to drive the pistons down on the power stroke.

The ECM will operate down to as low as 5.7 volts DC (direct current). The ignition control module offers protection against:

1. Damage due to jump-starts.
2. Constant reverse voltage protection.
3. Transitory voltage.

Dwell Time

Dwell time also known as the dwell period is the amount of time current runs through the primary circuit of the ignition coil. The ECM microprocessor calculates the dwell time. Therefore, the ECM calculates sufficient dwell time for the coil's primary circuit to build up necessary current to eventually jump the spark plug gap. Eventually measures in milliseconds.

Dwell time depends on engine rpm and expands as engine speed increases to compensate for the shorter time period. The ECM microprocessor programs the dwell period to provide sufficient current to the primary windings of the ignition coil depending on engine speed *without draining the battery.*

A Brief History of Original* Harley-Davidson Spark Plugs

Year	Application	Part Number	H-D Plug	Champion	Gap
1948-E1975	FL	32305-48A	2	H-L	.028-.033
1973-E1975	FX	32305-48A	2	H-L	.028-.033
1973-E1975	FL-FX	32301-60	3-4	J12YC	028-.033
1952-1978	K [1], XL, XLH	32305-48A	2	H-L	.028-.033
1956-1974	G [2]	32305-48A	2	H-L	.028-.033
1954-1970	K, XL, XLH	32307-58	5	J13YC	.028-.033
1958-E1975	FL, FX, G	32307-58	5	J13YC	.028-.033
1958-1977	XLCH	32307-58	5	J13YC	.028-.033
L1975-E1977	FL, FX [3]	32309-69	5-6	N12YC	.023-.028
L1975-E1977	FL, FX	32310-77	5A6	RN12YC	.023-.028
L1977-1979	FL [4]	32310-78	5A6A	N12YC	.038-.048
L1977-1979	FL	32310-77	5A6	RN12YC	.023-.028
L1977-1979	FX	32312-78A	5RL [5]	RN13LYC	.038-.048
L1977-1981	FL, FX	32312-78	5R6A	RN12YC	.038-.048
1972-1979	Sportster	32301-47A	4-5	H10C	.030
1980-1981	FLT	32312-78	5R6A	RN12YC	.038-.048
1982-1984	FL, FLT, FX	32312-78A	5RL	RN13LYC	.038-.048
1983-1985	XR-1000	32314-83	6R7	RN7YC	.038-.043
1980-1985	Sportster	32301-80	4R5	RL82YC	.038-.043
1984-1999	Evolution	32311-83	5R6A	RN12YC	.038-.043
1986-1987	XL 1100	32317-86A	6R12	RA8HC	.038-.043
1986-Present	Evolution XL	32317-86A	6R12	RA8HC	.038-.043
1999-Present	Twin Cam	32317-86A	6R12	RA8HC	.038-.043
Sprints, Baja, & Lightweight Motorcycles under the H-D banner					
M50, M65, Z90, L1974 SX-125		32308-71	6	N-4	.20-.25
1961-1973 Sprints, 125, 175, 250, M50, M65, ML, X90		32306-61	7	N-3	.20-.25
1974-up 125, 175, 250		32344-74	7-8	N-2	.20-.25

*Original H-D spark plugs and specified electrode gap settings were often superseded by updated plugs and modified gap settings as time went on. For example some update spark plugs had reduced gaps from .038-.048 to .038-.043.

[1] K is Sidevalve Flathead 750cc/45c.i predecessor to the 900cc (883cc) OHV Sportster. Spark plug part number 32305-48A was obsolete in favor of 32307-58. However, this did not take into account all the early bikes that were still on the road. The aftermarket is always there to serve these bikes and their riders.

[2] G is Sidevalve Flathead 750cc/45c.i Servicar

[3] Inactive part number is now obsolete. It is superseded by a current number 32310-77.

[4] Coincides with the first electronic ignition, which is not powerful enough to jump a gap this wide. It became obsolete and was superseded by part number 32310-77, which uses a smaller electrode gap. It also was not a resistor plug (RFI); it was negatively influenced by external radio wave frequencies.

[5] R = resistor plug. Resistor plugs are used with electronic ignitions. They are not influenced by external radio wave frequencies. A resistor spark plug can be used with a points-condenser ignition. A points-ignition non-resistor plug cannot substitute with an electronic ignition as they are susceptible to external radio frequencies.

[5] L = suitable for low compression engines. H-D began lowering compression ratios during these years because gasoline compounds also changed for sophisticated automotive head designs and ignitions. H-D was being left behind until the advent of the Evolution with a superior D-shape combustion chamber and the V-Fire III electronic ignition with a VOES switch.

ECM Ignition Advance Curves

The ECM has two programmed ignition advance spark curves:

1. The High Vacuum Curve advances ignition spark to its maximum 20^0, 35^0 BTDC, 42.5^0 BTDC, or 50^0 BTDC depending on Evolution year and model for cruise situations, which is the majority of normal riding. This spark advance offers improved fuel economy.
2. The Low Vacuum Curve retards ignition spark to 5^0 BTDC or 0^0 TDC depending on Evolution year and model for maintaining performance while minimizing the great engine destroyer, detonation also known as knock, spark knock, or pinging.

The V-Fire III Ignition Coil

The V-Fire III's 12-volt coil is dual fire. It is a *pulse type transformer*. The coil takes the relatively low battery voltage of 12 volts in *pulse* form thanks to the sensor and rotor creating Hall voltage. It then *transforms* the low battery voltage into the high voltage required to jump the spark plug electrode thus igniting the air-fuel mixture.

V-Fire III Ignition Hall effect Trigger Rotor

The ignition rotor locates in the gear case cover and bolts to the end of the camshaft by a short and skinny 10-32 x ½" bolt (H-D 2611B). The ignition trigger rotor consists of:

1. An inverted cup with two slots cut out of its external edge.
2. It rotates so that the slot cutouts interfere with and break a magnetic field created by a Hall-effect device. The difference is called Hall voltage.

Hall voltage creates across a current-carrying metal strip when placing the metal strip perpendicular in a magnetic field. The Hall effect creates when the inverted and rotating trigger rotor cup (32401-80) moves around the fixed sensor assembly (32400-80, 32400-80A, 32404-90, 32448-95A, 32406-96). The slots in the external edge of the trigger rotor break the magnetic field created by the Hall effect device mounted on the sensor plate. The Hall voltage or signal from the Hall effect device corresponds to the timing information from the precisely cut cup slots.

Hall Effect Advance and Retard Settings

Hall effect is all about ignition spark timing during the compression stroke.

1. Starting ignition spark timing is between 5° BTDC and 0° TDC where the piston is close or at top dead center at the end of the compression stroke just before the beginning of the power stroke.
2. Running spark ignition advance will vary among the retard setting of between 5° BTDC and 0° TDC and the full advance setting of 20°, 35°, 42.5° or 50° BTDC on all Evolution models. Consult your manual for the settings of year and model.

Ignition and Fuel Delivery Begin to Integrate

The V-Fire III electronic ignition and fuel delivery are no longer separate functions on bikes utilizing this system from 1984 through 2000.

The V-Fire III is very reliable. It is the basis for the modern and progressive *engine management system* that coordinates fuel delivery with ignition spark timing. The first sensor arrives in 1984 with the VOES that monitors vacuum inside the carburetor manifold. The VOES sends this information via electrical signal to the ECM (electric control module), which coordinates the first ignition spark delivery with engine load. Engine load or how hard the engine is working (idle, cruise, or acceleration) is indicated by vacuum in the manifold. This also specifies the level of fuel delivery.

I have included pictures and detailed descriptions of points/condenser, V-Fire I, V-Fire II, and V-Fire III ignition components in Volume III: *The Evolution: 1984 to 2000.*

The V-Fire III Engine Management System

In 1984, with the advent of the Evolution, Harley-Davidson begins to achieve ongoing tremendous strides in managing all aspects of engine running. The management system must balance the sometimes-contradictory goals of producing:

1. Power.
2. Efficiency.
3. Fuel economy.
4. Less noxious emissions.

Modern electronic ignitions produce higher voltages of anywhere from 25,000 volts to about 40,000 volts that are necessary to jump a much wider spark plug gap of .038” to .043”. The purpose of this wider gap is to ignite a much leaner air-fuel ratio. Point’s breaker ignitions only produce about 15,000 volts to about 20,000 volts that can only jump smaller electrode gaps of .028” to .030”. Thus a richer air-fuel mixture is required for this dinosaur ignition. Initial electronic ignition coils produced voltage somewhere in between. Hence, full solid-state electronic ignitions like the V-Fire III will:

1. Burn more of the air-fuel mixture.
2. Consume a higher percentage of otherwise harmful emissions.
3. Create higher gas mileage with the same amount of fuel.

The VOES Vacuum Operated Electrical System

The vacuum advance-retard unit (VOES) advances or begins ignition timing earlier in relation to piston travel up the cylinder on the compression stroke with higher piston speeds. It also slows initiation of retard ignition timing whereby spark occurs when the compression cycle piston is further up the cylinder with lower piston speeds as with initial starting.

This is overly simplistic and not quite correct since the VOES only signals the ECM when vacuum increases or decreases via electric pulse or signal. The ECM coordinates the VOES signals to advance and retard ignition-spark-timing in order to produce more power and to increase fuel economy.

Combustion Lag

Ignition timing is necessary because of *combustion lag* in combination with changing piston speeds. The size of cylinder bore is also a factor since it can increase the distance the flame front must travel across the combustion chamber. This is all about the time it takes the air-fuel mixture to combust or burn.

Gas burns very slowly at first. The molecules begin to move with warmth and progressively agitate with heat before beginning the actual process of ignition or burning. After this *combustion lag* process of heating up molecules has occurred, the gas burns at a consistent and known rate, which allows for the *timing* of full combustion to complete at the most opportune time to drive the piston down on its power stroke with the maximum possible burning expansion pressure. Ignition timing is about maximizing power.

The chemical soup known as Octane stabilizes gas burning to an unwavering and consistent rate. Furthermore, without Octane, gas may haphazardly explode causing great damage as opposed to a dependable steady burn.

The spark plug must spark sooner to allow for the extra time that combustion lag takes.

Advance, Retard Ignition Timing

An engine management system needs carburetor vacuum conditions to initiate and coordinate advance or retard ignition timing. Burning fuel takes time and obviously creates heat. The expansion of this heat creates pressure to force the piston down to turn the flywheels, which drives the power train to turn the rear wheel. For our purposes, *heat and pressure is the same thing* and are interchangeable. There is no pressure without heat and no heat without pressure.

So where must the piston position when the ECM ignites the spark plug? Theoretically, the piston should be at the top dead center (TDC), as far up as it can travel, compressing the air/gas mixture at the end of compression stroke and beginning of the subsequent power stroke when the spark plug fires. This means that ignition timing is at 0^0 TDC with no advance or retard. In actuality, most Evolution models over many years use 0^0 TDC as the retard timing position. This setting designs to meet emissions controls. Performance ignitions will always initiate spark before TDC in order to complete combustion at the most opportune time to create maximum heat-pressure to drive the piston down on the power stroke.

Ignition Settings are in Degrees of Flywheel Rotation

There is 720^0 of flywheel rotation to complete the four strokes (180^0 each) that complete one total cycle of engine activity. The four strokes that repeat continuously are:

1. Intake (intake valve open, exhaust valve closed) is the first stroke where fresh air/gas enters the cylinder via vacuum created by the descending piston.

2. Compression (both valves closed) where an upwards-moving piston compresses the gas mixture.
3. Power (both valves closed) where the burning mixture produces pressure to force the piston downwards.
4. Exhaust (intake valve closed, exhaust valve open) is the fourth and final stroke where the upward moving piston forces spent exhaust gases out the valve into the exhaust port and then the pipes.

These are theoretical, simplistic valve openings and closings. In real life, the valve openings and closings overlap one and another to take advantage of physics principles like scavenging and to compensate for mechanical valve opening and closing lag times.

I have been discussing retard ignition settings, which are used for engine starting and cold idle. The pistons are moving very slowly. However, as the engine heats up into hot idle, rpm begin to rise. Accelerating from hot idle to cruise situations means the pistons are moving much faster up-and-down the cylinders. In these situations, there is not enough time to begin burning the air/fuel charge at 0^0TDC of the power stroke to effectively drive down the piston on its power stroke. In fact, the burning fuel pressure may be trailing the piston movement and may even continue into the next exhaust stroke, which has no benefit whatsoever.

The Beginning: ECM Fuel-Spark Map for EFI

Electronic Fuel Injection fuel and spark maps (tables) are a biggie in integrating fuel delivery and ignition timing. It may seem conceptually intimidating and yet, when explained is disarmingly simple.

1. Fuel and linking spark maps that chart every throttle position combining with load or how hard the engine is working are memorized inside the electronic control module.
2. Each combination of load and throttle position sent to the ECM via sensors gets its own cell in a fuel/spark map.
3. The ECM computes fuel delivery requirements from each memorized throttle position and engine load map cell. The ECM signals the EFI injectors to turn on. It also computes pulse width or how long the injectors will squirt fuel by cell location in the map or table.
4. Each cell or section of cells link to another table called a spark map or spark table. The linking ignition-timing table or map instructs the advance or retard positioning for the spark plugs to fire.

Engine sensors deliver electrical pulse information to the ECM, which simply refers to the fuel/spark map to determine how much fuel pulse width and advance-or-retard spark timing to send to the injectors and spark plugs.

The settings are nothing more than a memorized response map from a dyno laboratory. EFI is so simple because it does all the work. Setting up and designing EFI as well as laboriously simulating actual riding conditions on a dynamometer in a scientific lab to develop the *memorized* fuel delivery and spark ignition tables is not so simple.

The (EMS) Engine Management System (2009)

Please see section *Carbureted Integrated Ignition* in the preceding chapter *Twin Cam Fuel Delivery* for the beginning of engine management in later Evolution years. This current section demonstrates the sophistication achieved in a few short years. The 2009 engine management system consists of seven primary mechanisms:

1. The ECM (electronic control module).
2. The CKP sensor (crank position sensor).
3. The TMAP sensor (temperature and manifold absolute pressure sensor).
4. The ET sensor (engine temperature sensor).
5. The TGS sensor (twist grip sensor aka fly-by-wire sensor).
6. The TCA (throttle control actuator).
7. The 0_2 sensor (oxygen sensors: one in each exhaust pipe).

Plus:

- The EMS further consists of the VSS (vehicle speed sensor), which now integrates into the engine management system.
- The HDI (Harley-Davidson International) Active Exhaust Actuator (AEA).

The following components complete the Engine Management System:

1. Ignition coil.
2. Fuel pump.
3. Two fuel injectors (one for each cylinder).
4. Solenoid purge.

Purge Solenoid

The purge solenoid activates to allow the fuel vapors to return (escape) from the charcoal canister back into the induction throttle body for re-burning in the combustion chamber. The purge solenoid times to the throttle position but is disabled when:

1. Motorcycle is started.
2. The engine is cold.
3. There is low engine rpm.
4. There is low motorcycle speed.

Purge solenoid activation power comes via the System Relay that triggers it to open when the ECM provides the path to ground thus completing the circuit.

Electronic Control Module

This tough irreparable solid-state *brain* is very effectively sealed against the elements and the ongoing threat of vibration. The ECM has many functions among them protection against:

1. Transient voltages that can interfere with legitimate sensor low-voltage signals of input data.
2. Reverse voltages.
3. Errant jump-start battery boosting procedures by the owner or mechanic.

However, the primary ECM functions that contribute mightily to the management side of the EMS are:

1. A fixed fuel map in the ECM determines when and for how long the two fuel injectors, one for each cylinder, turn on and remain on (pulse width) depending on engine load and piston speed. Pulse width measures in milliseconds (thousandths of a second).

2. Controlling ignition coil dwell time, which I cover in more detail earlier in this chapter under *Dwell Time*. Briefly, this develops optimal advance/retard ignition settings (0^0 TDC full retard ranging to 50^0 BTDC full advance ignition) for all engine loads (cold idle and acceleration) engine no-loads (hot idle and cruising) and resultant piston speeds. There is a preset fuel map table or matrix that coordinates and triggers the fixed ignition spark map table (matrix) for advance/retard settings matching differing loads and piston speeds.

Sensors

The sensors supply input signal information to the ECM via low-voltage circuits for this express purpose. I cover elsewhere the locations and functions of the various sensors but I will review these including the CKP crank position sensor and the relatively new combination TMAP sensor that merges manifold ambient temperature and manifold absolute pressure (MAP) into one. Briefly:

1. The CKP sensor locates and mounts in the front of the left engine casing and is a magnet that generates an AC (alternating current voltage) to the ECM by *reading* 30-equidistant teeth cut into the outside rim of the left-side sprocket shaft power-side crankshaft flywheel. A TDC (piston top dead center) reference point is marked by a section of flywheel that has no teeth cut into it. The CKP sensor via the ECM can read piston location and speed since moving internal engine components time to each other including flywheel rotational position. The ECM can even read the compression stroke because building pressure causes the flywheel crank to minutely slow down.
2. The TMAP sensor naturally mounts and locates in the top of the intake manifold; one segment measures ambient temperature via a thermistor element while the other segment measure air pressure moving past. The input information fed into the ECM in conjunction with the other sensors determines the output ECM instructions dictating both ignition advance/retard spark settings and fuel on-time to the EFI injectors.
3. The ET sensor operates via a thermistor element. As temperature changes, the electrical resistance in the thermistor changes. These changes inform the ECM whose output signals modify accordingly.
4. The TGS throttle grip sensor really needs to input two sources of information into the ECM; one for turning the throttle on and the other for turning it off. It does this with two opposing Hall effect sensors within the TGS main sensor. Thus one Hall effect sensor notifies the ECM when the rider turns the throttle on and the other when the rider turns the throttle off with all the stages in between. The ECM uses this information to signal the servomotor (also known as a throttle engine in Harleyese) on the EFI throttle induction body for throttle and this EFI control. Specifically, the rider throttle position movement and changes are received by the ECM as input signals. The ECM output signals to the TCA throttle control actuator, which controls the EFI induction body throttle plate. This is a long way from a mechanical throttle cable. For an explanation of Hall effect please see sub-sections; *V-Fire II Ignition Hall effect Trigger Rotor* and *V-Fire III Ignition Hall effect Trigger Rotor* earlier in this chapter.

5. The TCA throttle control actuator sensor mounts just before the intake manifold on the Delphi EFI induction body. The TCA operates the internal throttle plate just as a throttle and idle cable would on previous Harley-Davidson models. Two TP throttle position sensors receive output instructions from the ECM that corresponds to the TGS sensor input information to the ECM to operate the induction module throttle plate that opens and closes just like a cable-operated carburetor plate to allow air through the venturi (throttle induction body). EFI may inject the gasoline but air flow is still required to allow the fuel to combust. A throttle and idle manual cable system is easy to govern and if properly maintained, safe. A wonky electrical signal may cause real safety concerns for these TGS and TCA throttle sensors. Therefore, H-D includes what are called WatchDog and H-Bridge microprocessors for the equivalent electronic safety features. I know; I know what in the world do these terms mean? I'll try not to get too deep like write something as technical as an H-bridge driver IC (integrated circuits) is designed using its 0.8-um BCD-on-SOI technology. Instead, let's just say that this technology safely includes all the microcontroller features for the actuating throttle plate servomotor in what is called an H-Bridge configuration. A WatchDog circuit and method are provided for monitoring the microprocessor to detect the presence of a malfunction condition such as a program lock-up; nuff said! It works and it ensures safety.
6. An O_2 sensor locates in each exhaust pipe before the muffler. Their purpose is to monitor the exhaust gases for their *air-fuel-ratio* mixture. The sensors do this by monitoring the exhaust's oxygen content by measuring the resistance across each sensor's terminals for input to the ECM. If the exhaust air-fuel ratio is optimal, each O_2 sensor voltage will read near or at 0.45 volts. The ECM sends output signals to adjust the AFR delivered to the combustion chamber. Therefore, the intake AFR adjusts via the ECM depending on information sent to the ECM concerning the exhaust oxygen composition. New engine break-in period diagnostic codes that may appear via your dealership mechanic's DIGITAL TECHNICIAN II (HD-48650) or the speedometer self-diagnostic plug-in center should be ignored. Yes, the speedometer gets new important functions of identifying engine management system diagnostic codes. After engine break-in the mechanic will pay close attention to these diagnostic codes to figure out malfunctions, customer complaints, and problems. Of course, once a situation is diagnosed, the path to a correct repair becomes clear.
7. The VSS vehicle speed sensor locates into the transmission casing, usually beneath the starter motor. The VSS is another Hall effect sensor that monitors bike speed and reports this information to the ECM. It uses a reference point on the transmission 5th gear. The ECM sends a 5-volt reference signal to the VSS. The VSS and the ECM utilize common ground circuitry. The VSS, in return sends electrical signals back to the ECM. The ECM uses these signals to calculate motorcycle speed and then sends this information to the electronic speedometer via a serial data message. Again, this is a long way from the mechanical speedometer cable in use until about fifteen years ago. The electronic speedometer has evolved since its inception into a sophisticated and accurate monitoring device that also has diagnostic port capabilities since the reader can see that it communicates with the electronic control module. In an earlier section, I describe the electronic speedometer and the VSS sensor in the previous chapter *Twin Cam Fuel Delivery* in an earlier more simplistic state. The VSS sensor is now an integral part of the ever-developing and increasingly sophisticated engine management system. Please see the section on *Speedometer Self-Diagnostics* below. Furthermore, for an explanation of Hall effect please see sections; *V-Fire II Ignition*

Hall effect Trigger Rotor and *V-Fire III Ignition Hall effect Trigger Rotor* earlier in this chapter.

8. I mention the *active exhaust system* for Harley-Davidson International (HDI) readers whom it affects and for U.S. and Canadian riders for reference when they run across this foreign term (pun intended). The active exhaust system is an actuator valve in the rear exhaust pipe connected via a cable. The valve *automatically adjusts* to enhance engine performance via instructions from the ECM. What I think this really means is that it is an emissions device that may hinder performance in favor of less harmful exhaust emissions; so, yes it can improve performance when not hindering it. I know; I can be sarcastic.

Speedometer Self-Diagnostics

I am using a 2009 FLT for possible modules since the touring bikes will have a greater variety. Modules sectionalize ever increasing sophisticated functions and thus diagnostics. Other models like the Softail or the Dyna follows the same procedures outlined below but will not have the same number and variety of modules. For example a 2005 Dyna Glide will not have an ABS braking module or a 6th gear light, low-fuel light if carbureted, or a pursuit (police) light. EFI models will have the low fuel light. This stuff bounces around year-to-year and model-to-model. Please consult you manual for year and model for the most accurate information possible although manual information may also supersede and change.

The speedometer in diagnostic mode is able to display and subsequently clear diagnostic trouble codes (DTC) for the:

1. Speedometer.
2. Tachometer.
3. TSM (turn signal module).
4. TSSM (turn signal/security module).
5. HFSM (hands free security module).
6. ABS (anti-locking braking system).
7. ECM (electronic control module) DTC (diagnostic trouble code).

The WOW Test

This is a quick test to make sure the speedometer and test functions are working correctly. Press in the odometer reset switch and hold. Turn the ignition switch on to IGNITION. Everything is fine if the:

1. Background lighting illuminates.
2. Speedometer needle swings to its full range of motion.
3. Indicator lamps should light up. Some may light up even if the particular bike is not equipped with that option like; say cruise control or pursuit (police bike).
   a) 6th gear.
   b) Low fuel.
   c) Check engine.
   d) Battery.
   e) Security.
   f) Cruise enabled.
   g) Pursuit.
   h) ABS.

If failing the WOW test check the following:

1. Battery charge.

2. Ground.
3. Ignition.
4. Trip odometer reset switch.
5. Speedometer accessory wiring.
6. If all else fails there is a series of diagnostic checks listed in the manual.

Exiting a Diagnostic mode

Simply turn the ignition off to exit.

Clearing DTC's (Diagnostic Trouble Code's)

1. Press and hold the trip odometer reset switch for 5-seconds or more. This will display the available modules. Release reset switch.
2. Press the trip odometer reset switch in order to choose the module to be cleared.
3. Press and hold trip odometer reset switch for 5-seconds or more to display the DTC. Release rest switch.
4. Finally, press and hold trip odometer reset switch for 5-seconds or more to clear the DTC(s) for the module selected.

The Engine Management Ignition Coil(s)

Since Twin Cams use a single fire ignition, dual coils are required, one to operate each cylinder. What is confusing for the novice is that the manual will refer to the ignition coils in plural. He or she will be looking a long time to find two coils. One will be easily found but good luck on the other one. It all falls into place once the rider realizes that the front and rear coils, while separate are both in the same molded body and are inseparable. One more brain twister and I will go back to more logical information.

A single coil servicing two cylinders is dual fire; it fires the spark plug twice on each cylinder on the compression stroke and the exhaust stroke. This is necessary because each cylinder is on a different stroke sequence than the other.

1. A single coil servicing only one cylinder on a 2-cylinder H-D is a single fire coil that only fires on the compression stroke without firing a *wasted* second time on the exhaust stroke. Therefore 2-coils are required for an H-D single fire ignition.

Technology marches on with an extra terminal on the new late style Twin Cam coils. This is for an ECM connection for monitoring of the coil's secondary windings for:

1. Combustion diagnostics.
2. Spark knock (detonation) detection.

Heat is the Enemy

Increasing emissions dictates led to sealed ignition components and carburetor jetting. In later years, ignition timing becomes fixed preventing adjustment. With the 2006 Dyna and all 2007-to-present Twin Cams, the introduction of closed loop electronic fuel injection systems brought searing heat problems to the forefront. The Stoichiometric 14.7:1 air-fuel-ratios utilized with a closed loop system creates brutal engine temperatures that air-cooling finds difficult to assuage. The engine management system has to respond with sophisticated cooling attempts. I will start at the beginning where modern heat response to ultra-lean AFR's all started with the 2006 Dyna Glide.

2006 Dyna: Stoichiometric Heat Management

EFI models use a 3-phase heat management system in order to attempt to reduce engine temperature under what H-D refers to as extreme conditions. I think this a good idea under *all* conditions, which is why I recommend an oil cooler(s), synthetic oil, and other adjuncts such as larger oil pans, and especially an ignition/fuel modifier for the engine management system.

First Phase

If the engine temperature sensor (ET) signals the ECM that the cylinder head reaches a temperature of 320° F (160° C), the ECM will direct idle speed to gradually reduce. This rpm reduction will not generate as much heat as will the normal idle rpm of 950 rpm to 1050 rpm. Phase I heat control will cease to operate when idle reaches 800 rpm or engine temperature drops below the trigger figure of 320° F (160° C).

Second Phase

If the engine temperature sensor signals the ECM that the cylinder head reaches a temperature of 338° F (170° C); the ECM will direct the air-fuel-ratio to richen with more gas relative to air intake. Gas has a cooling effect since it is more air that creates the excess heat during ignition.

Third Phase

Phase III will only occur if the motorcycle is not moving. If the engine temperature sensor signals the ECM that the cylinder head reaches a temperature of 356° F (180° C); the ECM will direct the fuel injector to stop pulsing (supply gas). This, of course, interrupts ignition allowing air to flow through the combustion chamber with an effective cooling effect.

This methodology may sound contradictory to Phase II cooling since gas will eliminate in favor of just air pumping through the combustion chamber. Ambient temperature air from outside the engine is much cooler than the temperature inside the combustion chamber. The difference is that in Phase II, ignition is occurring where the lean air condition creates much heat and in Phase III ignition is not occurring because of interrupted gas delivery. When I write about these two seemingly contradictory methods of cooling cylinder head temperatures in *American Iron Magazine*, I get many letters from readers who feel that I am wrong.

Phase III heat management will be accompanied by a different noise because only one cylinder is firing and combusting while the other effectively becomes an air pump. There may or may not be an accompanying smell but all this is normal under Phase III heat management.

Please see the next section for an even more sophisticated heat management technique.

2009 Heat Management System: Engine Idle Temperature System

I describe the EITMS at length elsewhere. EITMS was a free one-time option on its inception in for 2007 to mid-2008 Twin Cams. It is now more user-friendly. This optional heat management system may be activated by your dealer upon request with the DIGITAL TECHNICIAN II (HD-48650). Once enabled EITMS will turn off the fuel injector to the rear cylinder when:

1. There are high engine temperatures.
2. The motorcycle is idling.
3. Or, there is low motorcycle speed.
4. Or, the transmission is in neutral.
5. Or, the clutch lever is pulled in disengaging the clutch.

The rear cylinder will act like an air pump without ignition so that cooler ambient temperature air flows through the cylinder while the front cylinder runs normally, powering the bike. The rear cylinder will automatically fire up with a working fuel injector when one of the above conditions changes such as speeding up or engaging the clutch and transmission.

Conclusion

It has been a long journey from primitive but long-serving point's and condenser ignitions that did nothing more than fire the spark plug to the modern engine management system where fuel and ignition co-ordinate at all levels. Information inputs to the ECM through a variety of sensors to allow the microprocessor to output intelligent instructions for ignition advance/retard spark firing and coordinated fuel injector on-times.

Furthermore, diagnostics are available through a data port, as well as the speedometer that has become a full partner in engine management, and a terminal on the newest single fire coils. Even throttle control is electronic discarding manual throttle and idle cables. Finally, the throttle also becomes integral with engine management.

CHAPTER X

The Controversial Harley 6-speed Transmission

Controversial, yes, the new six-speed, while a wonderful improvement, has its detractors in 2007 and 2008.

- Some say that upgraded performance packages do not give equivalent horsepower increases garnered if using a previous year Big Twin.
- Others complain of what they feel are disturbing noises emanating from the new transmissions and the primary chain case system.
- Harley-Davidson in convincing and soothing interviews responds that all is normal.

I will explore the veracity of these concerns. In order to understand the dramatic changes instituted by the Factory we first need background information.

Horsepower and Torque Management

Mismanagement of horsepower and torque gains often occur because of a general lack of knowledge about gear ratios. Production of power management at the engine transferring back to the rear wheel in usable amounts relative to engine rpm, mph speed, and load on the bike is the true key to a functional motorcycle whether it is for comfortable touring, stoplight racing, and everything in between.

Aftermarket Six-speeds

The aftermarket has been producing reliable and efficient 6-speed transmissions for a decade now, whether they be USA full-sized gear transmissions made by BAKER (www.bakerdrivetrain.com), or the first off-shore ones produced by Custom Chrome's performance line, Rev Tech (www.customchrome.com), with less beefy and lighter but stronger chromemoly gears with many newer manufacturers in between.

Offshore countries like Korea produce several variations of the above transmissions. The Harley rider should understand that reputable automotive transmission plants build many of these before the Harley rider conjures up visions of cheap unreliable products. As testament to their quality, some offshore brands come with full replacement 3-year full warranties. Others have two-year warranties. I do not know of any that do not have at least a one-year warranty.

The Rev Tech offshore overdrive six-speed comes with a limited warranty of five years/50,000 miles. Rev Tech used to have extended warranties on their six-speed builder's kits but have reduced the warranty period because of being unable to control the quality of the installations. Installers were making mistakes, causing problems that they naturally blamed on the transmission parts instead of their own ineptitude.

After I wrote a few years ago about offshore transmissions having better warranties than some American made products in *American Iron Magazine,* BAKER Drivetrain stepped up to the plate, fully confident in their American made quality products and offered a limited warranty of five years/50,000 miles for their excellent direct drive six-speed (DD6). Late in 2007, JIMS (www.jimsusa.com) announced that their American made transmissions, also of excellent quality, would now be backed with a six-year/60,000 mile warranty.

The price of aftermarket 6-speeds has plummeted in the last few years, dropping as much as 60%. American manufacturing is suffering as a result, but when was the last time Harley-Davidson dropped prices in such a dramatic fashion? Perhaps investor profit driven publicly owned companies like H-D have been focusing too much on bottom line shareholder wealth. Investors were getting rich off H-D stocks, but the workers from many American companies began to suffer as more production moved offshore.

The flip side is that share investment gives H-D the capital to reinvest in the development of a better quality product and expand its operations. In general, Harley quality is top-notch. Nevertheless, has H-D ever offered a full-replacement 3-year warranty? No, on factory-installed components Harley has not, although it did extend its motorcycle warranty from one to two years circa 2004. The consumer is hard-pressed to get a comprehensive warranty of any type if buying Screamin' Eagle (www.harley-davidson.com) performance parts like a complete six-speed transmission gear set However, I believe that H-D's parts are of excellent quality and some of superb design.

Gear Ratios: An Important Key

I am going to spend seemingly much time on Big Twin Harley-Davidson's exploring gear ratios and their historical use. The reader will discover the big differences in the 2006 Dynas, with more changes in the 2007 Big Twins in overall gear ratios. This is a major reason for the increased performance seat-of -the-pants feel of these new models.

The conundrum is that the increase in cubic inches does not offer hardly any more horsepower combined with the new 6-speed no-overdrive 6th gear.

An overdrive sixth gear lowers rpm in that final gear. H-D achieves a similar objective in its 1:1 final ratio direct drive six-speed. Harley does this by incorporating a new primary drive-gear reduction ratio of 1.35:1 as opposed to the 2005 ratio of 1.44:1. The new ratio spins the engine a slower pace of 1.35 times for one revolution of the clutch package, as opposed to a faster 1.44 times on 1994 to 2006 models, except the 2006 Dyna. Predecessor five-speeds from 1985 to 1993 have a ratio of 1.54:1.

Primary Gear Reduction Ratio

Calculate this ratio by dividing the number of teeth on the clutch hub sprocket by the number of teeth on the engine sprocket.

$$\text{Primary gear ratio} = \frac{\text{clutch sprocket teeth}}{\text{engine sprocket teeth}}$$

Therefore, the primary ratio for 2006 Dyna Glides and all 2007-to-present Twin Cams is:

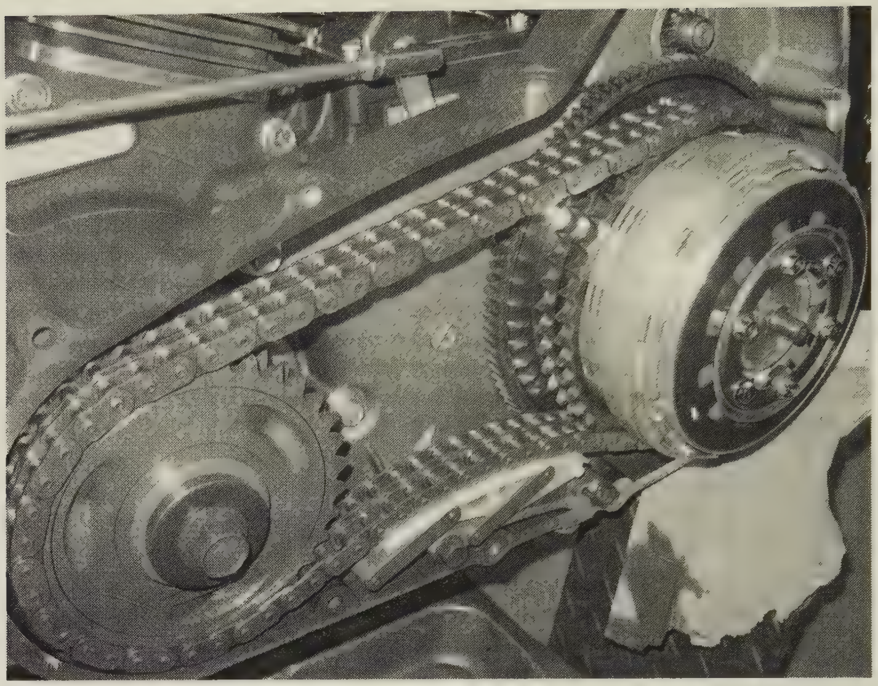
$$\text{Primary gear ratio} = \frac{\text{clutch sprocket teeth}}{\text{engine sprocket teeth}} = \frac{46}{34} = 1.35$$

Therefore, 2006 Dynas and 2007 Big Twins have a primary ratio of 1.35 engine rotations for one rotation of the clutch hub and, therefore, one rotation of the attached transmission mainshaft that the hub sits on.

Modern clutch hubs from 1990-to-present have fine-spline inside centers that mate with an outside splined transmission mainshaft that extends out from the transmission and into the inside of the inner primary casing connecting the primary powertrain to the transmission powertrain. Earlier models connected the clutch hub to the transmission mainshaft via a press fit keyway that was not as strong or concentric as the splined method. Unless the clutch hub sits perfectly in alignment with its supporting transmission mainshaft, it will be a huge source of vibration.

- Big Twins from 1994 to 2006 except 2006 Dyna Glides have 25-tooth engine sprockets combined with a 36-tooth clutch sprocket, giving a primary ratio of 1.44 engine rotations for one rotation of the clutch hub and the transmission mainshaft.
- Previous Big Twins from 1985 to 1993 had a 24-tooth engine sprocket combined with a 37-tooth clutch hub sprocket giving a primary ratio of 1.54 engine rotations for one rotation of the clutch hub and the transmission mainshaft.

The primary drive, consisting of the engine sprocket and clutch basket sprocket combining with the gearbox's internal gear ratios are designed to best utilize engine power and torque. It transfers engine power from the crankshaft to the clutch and the transmission. A primary chain connecting the smaller engine sprocket to the larger clutch sprocket on the front or back of the clutch shell depending on year that encases the steel and fiber clutch plates, accomplishes primary drive reduction.



TC96, TC103, and CVO 110 Twin Cam Primary System

Pictured is the 2007-to -present Twin Cam inner primary chaincase and the primary drive it houses. The front engine sprocket (40320-06) increases to whopping 34-teeth from the previous 25-tooth (40308-94) sprocket used from 1994 to 2006. The new duplex (double row), primary chain (40037-07 FLT, 40036-06 FXST/Dyna) connects the engine sprocket to the clutch sprocket, which increases to 46-teeth from the previous 37-tooth one. The sprocket has always been on the back of the clutch hub (37707-98A) behind the ring gear on previous Big Twins. Now, the clutch hub (37813-06A) sprocket moves inboard in front of the starter ring gear beginning with the 2006 Dyna TC88. The primary chain automatically keeps at proper tension by the new adjuster (39929-06A). The outer primary cover (removed), no longer has an inspection hole to check primary chain adjustment. Cardboard is a handy drain fixture wedged between the inner primary chaincase and the bike stand.

Overall Gear Ratios

Further reduction occurs with different-sized gearing in the transmission, combining with the size-transmission pulley and finally the size-rear-wheel pulley. I am using domestic USA sprocket sizing for all examples in this chapter except where otherwise noted.

Total reduction, also known as overall gear ratios, indicates the number of engine revolutions required to drive the rear wheel one revolution.

1. For example, a 1993 FLHT model engine turns through 3.37 revolutions in 5th gear in order to turn the rear wheel once through 360-degrees.

International models use smaller rear-wheel-pulleys for better highway cruising. This is especially important in countries where the speed limits are much higher. Some European highways like the famed autobahns in Germany have no top-end speed limits at all.

2. The 2005 domestic USA models' engine turns 3.15 revolutions in 5th gear to turn the rear wheel one revolution.

This difference is due to a change in primary sprocket sizes. The internal gear ratios, the transmission pulley (32-nubs), and rear pulley (70-nubs) remain constant.

The 1985 to 1993 5-speed models have a 24-tooth engine sprocket and 37-teeth on the clutch sprocket.

3. The 1994 to 2006 5-speed models use 25-teeth on the engine and reduce the clutch sprocket to 36-teeth.

The engine sprocket has more of an impact on gear ratio than the clutch sprocket on a per-tooth basis, as the transmission sprocket has a bigger impact than the rear wheel one.

4. When performancing 1994 to 2006 5-speeds I routinely retrofit the 25-tooth engine sprocket to a 24-tooth one for better off the line get-up-and go. This gives a primary ratio of (24/36=1.5), 1.50:1; turning the engine 1.5 times vs. 1.44 times using the stock 25-tooth engine sprocket for every clutch hub sprocket/transmission mainshaft revolution.

For those that only care about stoplight-to-stoplight drag racing, Screamin' Eagle borrowed a page, so to speak, from BAKER Drivetrain, the first developer of the 21-tooth engine sprocket for 1985 to 2006 five-speed models (#155-56S FLT-FXR; part # 155-56L FXST/Dyna). This sprocket is supplied with a mating-correct length primary chain. BAKER also has 22-tooth (#156-56S FLT-FXR; part # 156-56L FXST/Dyna) and 23-tooth (#157-56S FLT-FXR; part # 157-56L FXST/Dyna) kits complete with correct length primary chains.

For full accuracy, early Harley FL police bikes from the Panhead (1948 to 1965) and Shovelhead (1966 to circa-1985) eras sometimes used 21-tooth engine sprockets for faster get-up- and-go in city traffic. However, the engines just screamed on the highway. Highway police bikes of the era had engine sprockets up to 23-teeth to lower engine rpm.

1. The Screamin' Eagle 21-tooth engine sprocket offering (1994 to 2006 FXST/Dyna 40331-02: 1994-2006 FLT 40200-02) also available in its original form from BAKER changes the primary ratio from the stock 1.44:1 to 1.7:1. The 1.7:1 primary drive ratio that is 1.70 times (versus 1.44 times) causes the engine to spin at higher rpm at any speed. The politically correct Screamin' Eagle catalog blurb says "…will help you get the holeshot at the race track." [1]
2. A peppier 2006 Dyna/2007-to-present Big Twin off the line is achievable by replacing the stock 32-tooth transmission pulley (40659-06), with a BAKER Drivetrain 31-tooth or 30-tooth replacement.

Transmission Parts Comparison

2005, 2006 Dyna and 2007 Big Twins

Part Description	06 Dyna	07 Models	5-speeds
Starter gear, pinion	31345-06	Same	31342-94
Starter assembly complete	31618-06	Same	31553-94B
Starter clutch assembly	31626-06	Same	31516-94
Starter solenoid assembly	31631-06	Same	Different
Starter clutch	31632-06	Same	Different
Transmission housing	34747-06	34740-07	34740-02A
Transmission bearing inner race	34091-06	Same	Different
Gear assembly: 6th M.S. driven output	35122-06	Same	None
Guide Hub, dog ring: C.S. 1st/2nd [2]	35124-06	Same	None
Dog ring, lugged (2): C.S. 1st 2nd [1]	35126-06	Same	Different
Guide hub, dog ring: M.S. 5th 6th [2]	35201-06	Same	None
Guide hub, dog ring: C.S. 3rd 4th [2]	35202-06	Same	None
Dog ring, pocketed: C.S. 3rd 4th [1]	35204-06	Same	Different
Input shaft +3helical +1 spur gear integral	35467-06	Same	Different
C.S. assembly +1 spur + 1 helical gears	35470-06	Same	Different
Fifth gear input (M.S.)	35801-06	Same	Different
Gear: C.S. 1st	35805-06	Same	Different
Gear: C.S. 2nd	35807-06	Same	Different
Gear: CS 3rd	35811-06	Same	Different
Gear: CS 4th	35814-06	Same	Different
Clutch assembly with ring gear	37813-06	Same	Different
Clutch hub	37554-06	37554-06A	Different
Clutch diaphragm spring	37882-06	Same	Different
Primary chain	40036-06	40037-07	Different
Compensating assembly: 34 tooth	40296-06	Same	Different
Pulley rear	40576-06	40217-07	Different
Pulley front thirty-two-tooth	40659-06	Same	Different
Pulley rear international 68T (132T belt)	40535-06	1"Belt 136T	Different
Primary adjustor	39929-06	39929-06A	Different
Inner primary bearing	9231	Same	Different

[1] There are three dog rings in the H-D 6-speed, two (1st/2nd and 5th/6th) with dogs on either side, or one (3rd/4th) that is pocketed. The pocketed dog ring has no dogs or lugs but 6-indents on either side known as pockets. The advantage of these dog rings is that there is less inertia

involved in moving them back and forth to engage with their respective gears when compared with having to move whole gears to engage other whole gears, as in the 5-speed transmission.

[2] In order to make the dog rings even lighter with corresponding less resistance to movement known as inertia, they ride on guide hubs. The three guide hubs, one specifically for each dog ring is multi-splined inside and out. The inside splines rides on mating splines on their respective shaft, two on the countershaft and one on the mainshaft. The shift dog rings are also splined on their inside diameter to mate with the splines of the outside diameter of the guide hubs. This is a lightweight shifting mechanism that is nimble and has the least inertial resistance possible, a huge improvement over the bulky five-speeds.

2006 Dyna & 2007-to-present Primary Gear Reduction

I mention these overall ratios to illustrate a major change in primary reduction with the 6-speed 2006 Dyna and all subsequent 2007 Big Twins.

The 2006 Dyna engine turns over only 2.96 times per rear wheel revolution. The 2007 Big Twins turn over even less at 2.79 engine revolutions per one rear wheel revolution. Although both have the same oversized primary sprockets, the rear pulley is reduced to 66-nubs in 2007 from 68-nubs on the 2006-Dyna. Most previous Big Twins utilize a 70-nub rear pulley.

Modifying Primary and Secondary Ratios

A rudimentary guide to the effects of these external sprockets on engine performance via overall gear ratios follows a simple procedure.

- Firstly, reducing the number of engine sprocket teeth, increasing the clutch sprocket teeth, reducing the transmission pulley nubs, and increasing the rear pulley nubs will make the motorcycle faster off the line. These change(s) will increase rpm and acceleration. Radical tooth/nub changes in this direction will make the bike slower in the top end on the highway.
- The opposite changes, increasing the number of engine sprocket teeth, reducing the clutch sprocket teeth, increasing the transmission pulley nubs and decreasing the rear pulley nubs will make the motorcycle slower off the line decreasing rpm and acceleration. Dramatic tooth/nub changes will make the bike faster in the top end on the highway.
- Big cubic inches will help this latter scenario. A more powerful engine usually mandates higher gearing.

The Secret

Certainly, the 2007-to-present gear ratios would not be practical without the increase to 96c.i, a dramatic increase in torque, and closely matched internal six-speed gear ratios.

If there is a secret to the 2007 Twin Cams, then this it! Gear ratio performancing will be crucial to big gains with these later models in future years.

This will be accomplished with aftermarket parts, for the most part yet to be developed. Furthermore, compensator parts from 1989 to 2006 are not interchangeable with 2006 Dynas and 2007-to-present Big Twins. This is due to a change on the engine crank-sprocket shaft splines. The sprocket shaft extends into the primary where the compensator engine sprocket fits. Earlier models have 10-wide splines while the new bikes have 24-multi-splines.

Early builders of bigger-cube 2007-to-present TC96 engine models have noticed a measurable loss in horsepower compared the results if they had done the same upgrades to the

25/36 or the 24/37 primary reduction gears in earlier Twin Cams. We are all attributing this to the drastic changes in primary reduction sprocket and clutch gear sizing.

This also explains one major reason why the 2007 TC96 models do not have the expected increase in horsepower over the previous Twin Cam 88. However, there is a dramatic and positive increase in torque with the new TC96 configurations. This in combination with the primary, secondary, internal and final gear ratios gives the fastest accelerating Big Twin of all time.

Please remember that horsepower is a largely artificial measurement deriving from the very real engine torque. Torque is where it is at!

Comparing Six-Speeds

The H-D six-speed transmission will offer surprises when changing these external gear ratios to gain more horsepower. External ratios may need modification to coexist in a positive way with the Factory 6-speed when the engines are performanced. Combining these with a lot more powerful engines will involve creative sprocket/pulley changes to achieve desired results.

The stock H-D Cruise Drive 6-speed has a 1:1 internal ratio in sixth gear while the Screamin' Eagle 6-speed that is about six years late in development relative to excellent aftermarket offerings has an overdrive 6th gear with a ratio of 0.89:1. RevTech has offered a .8931 overdrive sixth gear ratio since around 1999.

The .089 overdrive 6-speed transmissions will lower rpm about 360 rpm in 6th gear. However, they are not for use in the 2006 Dyna or 2007-to-present Big Twins. Their initial fitment is for 1985-2006 Big Twins.

With the Harley 1:1 ratio four- and five-speeds, it is important that gear ratios be kept within bounds, known as the powerband, to ensure good start-off power along with acceptable highway cruising rpm on an all-purpose street Harley's. These are the tradeoffs with traditional 1:1 final transmission gear ratios with fewer gears.

A disadvantage of overdrive transmissions is that they require four gears to interact in 6th gear, and, strangely, so does the H-D Cruise Drive 1:1 ratio direct-drive 6-speed. An advantage of the BAKER direct drive is that a higher percentage of torque transfers through 6th gear relative to an overdrive transmission and the H-D direct drive because only the interaction of two gears are involved at this point.

Even though Harley-Davidson has done an initially satisfactory job with its 2007 transmission combined with primary drive gear ratios, I did not quite understand why H-D did not use an overdrive sixth. I say *satisfactory*, hesitantly, because there are changes that could make it better. We will see as this chapter progresses that H-D could have improved its six-speed design to reduce the transfer of torque power loss as well as addressing a nagging noise issue.

I asked "Mr. Transmission," the venerable Bert Baker what he thought; "Overdrive six-speeds are inherently noisy in sixth because it is virtually impossible to make a large gear on the mainshaft drive a small pinion on the countershaft quietly, which is the case on the 6th gear pair in 6-speed overdrives. High-quality transmission makers like BAKER spend a lot of money on grinding the flanks of the gear teeth after heat-treating to minimize these noises, whereas some lower-quality transmission makers do not. I feel that this inherent noise with six-speed overdrive designs is the reason why Harley did not opt for this route." [2]

Ya just gotta agree with the guy, his logic and knowledge just rolls along. Why would Harley-Davidson build an overdrive that is intrinsically noisier when the whole goal of the internal helical gears was to appease the noise cops? I feel that the H-D six-speed transmission will be improved in coming years. The H-D six-speed or related components may even be in for a redesign since Harley riders are not as sensitive to noise as the environmental folks are. See section, *The IDS Fix or is that an Enhancement* later in this chapter as well as Chapter XV: *2010 Model Changes.* If customer complaints about noise were becoming an issue, the governmental agencies would not be far behind.

Bert continues, "Being that the H-D transmission is direct drive in sixth gear, like our DD6, there does not 'need' to be four meshed gears. Just sixth main and sixth counter meshed. The H-D design drives three gears and has a fourth along for the ride. It does not utilize the advantages that a 1:1 drive ratio can give you. In a traditional overdrive six-speed the four meshed gears are needed to reduce the drive ratio below the 1:1 threshold to the (.89) .86:1 or .80:1 ratio depending on the transmission. Not so with (our) Direct Drive." [3] As Bert mentioned, there are also .086 and .080 final overdrive ratio six-speeds but these should be combined with progressively bigger-inch bikes to achieve a satisfactory all-around powerband.

The H-D Cruise Drive (www.harley-davidson.com), BAKER DD6 (www.bakerdrivetrain.com), and the S&S (www.sscycle.com), 1:1 ratio six-speeds attains their goals through another method: changing the primary or secondary sprocket/pulley ratios.

Both the BAKER and the H-D transmissions feel like they are overdrives in sixth gear even though they are not. Harley and BAKER got around the overdrive advantage by supercharging the primary gear ratio.

1. The conservative S&S 1:1 six-speed uses a 34-tooth transmission pulley up from the stock 32-nub pulley.
2. BAKER's DD6 (Direct Drive 6) 1:1 comes with a huge 28-tooth engine sprocket and longer primary chain. Huge, because it retains the stock clutch hub of 36-teeth or 37-teeth depending on year instead of increasing to 46-teeth.
3. BAKER has also developed a sportier 27-tooth compensating sprocket for use with his Direct Drive 6-speed.
4. H-D's stock 1:1 direct drive six-speed comes with the really big 34-tooth engine sprocket, but the gear ratio is also modified with an increased clutch sprocket from the stock 36-teeth to a whopping 46-teeth.
5. When using stock pre-2006 clutch, transmission, and rear wheel pulley/sprockets, Bert Baker's DD6 allows the rider to mimic the 2006 Dyna- 2007 Twin Cam's gear ratios. BAKER's final drive ratio of 2.83:1 is right in the middle of the 2006 Dyna's 2.88:1 and the 2007 Big Twin final drive ratio of 2.78:1.
6. The S&S six-speed comes in at 2.97:1, lower than the 1985-93 Big Twins but higher than the 1995-2006 (except the 2006 Dyna) models.

The S&S transmission has a different goal than the other manufacturers in keeping with turndown ratios, which I will discuss later.

The BAKER 7-Speed TC96 Transmission

The BAKER DD7, Direct Drive 7-Speed is a direct replacement of the Cruise Drive Harley-Davidson factory 6-speed improving it in addition to adding another gear.

The DD7 has a shorter first gear for improving get-up-and-go. As a result, of the shorter first gear and following gear ratios, the bike will feel like it has enhanced engine work. The BAKER DD7 transmission has the following ratios with comparative H-D Cruise Drive ratios in brackets:

- 1st: 3.76 (3.34)
- 2nd: 2.75 (2.30)

- 3rd: 2.06 (1.71)
- 4th: 1.55 (1.41)
- 5th: 1.27 (1.18)
- 6th: 1.10 (1.00)
- 7th: 1.00 (NA).

I believe the shift quality is much better. In transmission design, a low mainshaft weight is always desirable for smooth and quiet shifts. The H-D mainshaft is an integral one-piece design that includes first, second, third, and fourth gears. The heavy rotating weight and the resultant high inertia of the 1-piece forged mainshaft creates the audible shift clunk in the Cruise Drive 6-speed.

The BAKER DD7 mainshaft is lightweight and only includes the small first gear as an integral part to reduce weight. Therefore, the shift clunk substantially minimizes.

To put all this in perspective, shift smoothness in the Factory 6-speed is a definite improvement over the predecessor 5-speed. The DD7 is a big improvement over the H-D 6-speed because it incorporates a new linear roller ball detent as part of the supplied billet top cover. This linear roller ball detent is similar to the technology in first use in the BAKER TorqueBox transmissions. The detent is simply a spring loaded ball bearing that keeps the gear selection in place, it's the click you feel when shifting between gears, much like the ball on a ratchet wrench that holds a socket from falling off.

The BAKER DD7 shift drum design helps the rider find neutral every time.

The Factory 6-speed has straight cut first and fifth gears, which yields gear noise in these gears most noticeably in fifth. The BAKER DD7 has a full set of helical gears for quiet operation in every gear.

In summary, the BAKER DD7 design features include:

- Ease of Finding Neutral.
- Smooth Shifting.
- Clunk and jerky shift reduction.
- Utilizes ball bearing linear detent in the top cover that was an original design for the BAKER Torque Box.
- The DD7 Builder's Kits will come ready to slide in the bike with no stock 6-speed case modifications, shimming of the gear set or adjustments.
- The 7th main drive gear bearing and seal are included to replace the stock sixth gear components.
- Superior hardware fasteners, ARP (Automotive Racing Products) 12pt bolts for trap door, top cover and the stock side cover.
- Includes the BAKER speedo re-calibration.
- Utilizes the BAKER F6F Door Bearing Retainer Plate.
- DD7 trap door bearings are 28% wider than stock.

Sprocket Change Limitations

The rudimentary sprocket/pulley changes are not practical in every case nor are changes made to every sprocket in everyday usage. Fixed sprockets on different years and space limitations affect the amount of change on most years, although these are not hindrances to achieving changes in gear ratio goals in recent years. On modern Harley's, modifications are possible only on the engine, transmission, and rear sprocket/pulleys.

The clutch sprocket remains fixed on the majority of years. They can change by one tooth from 1990 to 2006 by swapping the clutch package and some starter parts, but this is hardly practical.

Early Sprocket and Pulley Changes

Pre-2006 primary casings have no problem in accommodating wild off the line 21-tooth or 22-tooth sprockets to the more lethargic 24-tooth or 25-tooth stock engine sprockets. Rear belt drive models have a choice of going up or down a few nubs on the transmission pulley. Rear pulleys are common in a range from 61-nubs to 70-nubs with correspondingly different-length H-D and aftermarket belts to accommodate them.

There is no hindrance whatsoever in making whatever changes necessary for a particular sized engine and type of riding combined with rider and bike weight. Yesteryear models, before the advent of the rear disc brake in 1973, were restricted in their choice of ratios by both the lack of aftermarket parts for the compensator engine sprockets and by fixed non-changeable clutch and rear 51-tooth chain sprockets. They were integral with the clutch shell and rear brake drum respectively.

However, twenty-one- and twenty-two-tooth engine sprockets were readily available from the Police FL models and twenty-three-tooth ones available from later FLH citizen Big Twins.

Different-length primary chains were also more difficult to get unless eliminating the endless chain by splitting it, cutting, or adding to the length and rejoining, using a master link(s). BAKER has resolved these issues for modern riders with its sprocket and primary chain kit combinations.

Most changes made during the old days were to the transmission sprocket, which came in every size from 19-teeth to 25-teeth, the 24-tooth aftermarket sprocket being the most popular. I liked the 25-tooth sprockets just as much but interference with the starter housing after 1965 became as issue with a loose or unevenly stretched rear chain.

These restrictions combined with a 4-speed transmission with a 4th gear 1:1 ratio limited choices along with the anemically powered Shovel and predecessor engines. I use the past as a reference comparison to the liberal changes allowed today with five- six and seven-speed transmissions in combination with the wide array of the non-fixed sprocket/pulleys excepting the clutch sprocket available from both Harley and the aftermarket.

The Ring Gear

Do not confuse the clutch sprocket located at the rear of the clutch shell with the ring gear located on the outer perimeter of the clutch shell. The ring gear is part of the starter mechanism whereby a shaft with a much smaller gear forces out to engage and turn the ring gear when the starter button on the handlebars is pushed. This, of course, activates the starter motor and triggers the starter solenoid, which thrusts out the smaller starter jackshaft gear to engage the ring gear. Because both the ring gear and the clutch hub sprocket are a fixed part of the clutch hub, the starter motor turns the whole hub.

The primary chain connects the clutch sprocket to the engine sprocket, thereby turning the crank, moving the pistons up and down in their respective cylinders, drawing in fuel, and the sparking spark plugs fire the engine. At this point, the rider removes his thumb from the button, the starter gear retracts, and the starter motor deactivates.

Since the primary engine sprocket is always smaller than the clutch sprocket, gear reduction is accomplished whereby the clutch turns slower than the crank and its attached engine sprocket. This also achieves an increase in the turning force defined as torque.

Secondary Drive Gear Ratios

The relative sizes of the transmission pulley/sprocket and the rear wheel pulley or chain sprocket determine secondary drive ratios.

$$\text{Secondary gear ratio} = \frac{\text{wheel pulley teeth x high gear ratio}}{\text{Transmission pulley teeth}}$$

High gear ratio refers to the final gear ratio inside the transmission, which for all H-D stock four- 5- six-speeds is 1:1. Therefore, the secondary drive ratio for the following year Harley-Davidsons' is:

1. The Shovelhead FLH is (51/23 x 1.00 = 2.22), 2.22, which means the transmission sprocket and transmission mainshaft turn 2.22 times for 1 rotation of the rear wheel sprocket. To state the obvious, the rear wheel turns one time for each revolution of the wheel sprocket.
2. The secondary gear ratio for all rubbermount five-speeds from 1985 to 2006, excepting the 2006 Dyna, is the same at 2.19:1 (70/32 x 1.00 = 2.19) since they all use a 70-tooth rear wheel pulley and a 32-tooth front transmission pulley. Therefore, on these models the transmission pulley and transmission mainshaft turn 2.19 times for one rotation of the rear-wheel sprocket.
3. The 2006 Dyna Glides still use a 32-tooth transmission pulley but a reduced 68-tooth rear-wheel pulley (68/32 x 1.00 = 2.13). This results in the transmission pulley and transmission mainshaft turning 2.13 times for one rotation of the rear-wheel sprocket.
4. All 2007 to 2008 Twin Cams calculates by using the 32-tooth transmission pulley and the further reduced 66-tooth rear-wheel pulley (66/32 x 1.00 = 2.06), resulting in the transmission pulley and transmission mainshaft turning 2.06 times for one rotation of the rear-wheel sprocket.
5. Finally, the 2009 Twin Cams revert back to the 2006 Dyna combination. A 32-tooth transmission pulley with a now, increased 68-tooth rear-wheel pulley (68/32 x 1.00 = 2.13). This results in the transmission pulley and transmission mainshaft turning 2.13 times for one rotation of the rear-wheel sprocket.

Both primary and secondary drive ratios have steadily decreased, producing smaller final drive gear ratios over the years to the lowest levels ever.

Final Drive Gear Ratios

I will now explain how to calculate the final drive gear ratios. Most riders and enthusiasts are concerned with this ratio. The primary and secondary ratios determine the final drive ratio.

Final drive ratio = primary gear ratio x secondary gear ratio

1. Therefore, the 1973 Ironhead XL 1000cc final drive ratio is (1.74 x 2.43 = 4.23 or 4.23:1), which means the engine turns 4.23 times for each rotation of the rear wheel.
2. The FLH is (1.61 x 2.32=3.74 or 3.74:1) turning the engine 3.74 times for each rotation of the rear wheel.
3. All 1985 to 1993 rubbermount 5-speeds is (1.54 x 2.19 = 3.37 or 3.37:1) turning the engine 3.37 times for one rear wheel rotation.
4. All 1994 to 2006 models (except the 2006 Dyna) is (1.44 x 2.19 = 3.15 or 315:1), turning the engine 3.15 times for one rear wheel rotation.
5. The final drive ratio for the 2006 Dyna is (1.35 x 2.13 = 2.88 or 2.88:1) turning the engine 2.88 times for one rear wheel rotation.
6. All 2007 to 2008 Twin Cams is (1.35 x 2.06 = 2.79 or 2.79:1) turning the engine 2.79 times for one rear wheel rotation.
7. All 2009 Twin Cams is (1.35 x 2.13 = 2.88 or 2.88:1) turning the engine 2.88 times for one rear wheel rotation.
8. The final drive ratio for the BAKER DD6 is (1.29 x 2.19 = 2.83 or 2.83:1) turning the engine 2.83 times for one rear wheel rotation.
9. Lastly, the final drive ratio for the S&S six-speed is (1.44 x 2.06 = 2.97 or 2.97:1)
10. turning the engine 2.97 times for one rear wheel rotation.

Changing the rear pulley size can easily modify the BAKER and S&S six-speed final drive ratios as it will with any of the stock H-D ratios.

Breaking in my 2007 Street Glide

My personal riding examples will exemplify the effects the Cruise Drive 6-speed transmission has in conjunction with its supportive gear ratios has on break-in and broken-in engine speeds through rpm reduction. The break-in procedure as with any Harley-Davidson involves gradually and alternately increasing, then decreasing *conservative* engine rpm to allow mating parts like cylinder walls and piston rings to wear into each other.

1. I have owned many 4-speed Shovels over the years. The FLH models had higher gearing for adequate city riding. They allowed comfortable lower highway speeds for the era but not very high ones. My Shovels would not allow me to attain main highway speeds during break-in periods for a new engine. I had to stick to secondary two-lane highways and suburban thoroughfares in order to keep the engine rpm to an acceptable level. Even when broken in, these bikes simply cannot keep up with the sustained highway speeds that the Evolutions effortlessly make.
2. My stock-geared 5-speed Evolutions were much easier to break in than the Shovelheads in today's fast moving world. I could easily stay in highway slow lanes while putting the first all-important miles on them. Once broken in, I have ridden many Evolutions on cross-country trips at a steady 80 mph. A Shovel can only *reliably* do this at 60 mph.
3. I owned a 2006 FLHXI 5-speed Street Glide that I took onto a major highway with less than twenty miles on it. My friends promised to stay at 60 mph or less, so I could gradually break in the engine. Soon, they forgot their promise, and we were riding at 65 mph and then 70 mph. It was a cool day, and the engine suffered no ill effects. When broken in, sustained speeds of 90 mph to 100 mph did not burden the bike at all.

Sprocket/Pulley Sizes

Primary: Secondary and Final Drive Ratios

SPROCKET	NUMBER OF TEETH-USA MODELS								
	1973 XL	FL Shovel	1993	2005	2006 Dyna	2007 2008	2009	DD6	S&S
ENGINE	34	23	24	25	34	34	34	28	25
CLUTCH	59	37	37	36	46	46	46	36	36
Primary ratio	1.74	1.61	1.54:1	1.44:1	1.35	1.35	1.35	1.29	1.44:1
TRANSMISSION	21	22	32	32	32	32	32	32	34
REAR WHEEL	51	51	70	70	68	66	68	70	70
Secondary ratio	2.43	2.32:1	2.19:1	2.19:1	2.13:1	2.06:1	2.13:1	2.19	2.06
Final drive ratio	4.23:1	3.74:	3.37:1	3.15:1	2.88:1	2.79:1	2.88:1	2.83:1	2.97:1

The reason that 2006 Dynas and 2007 to 2008 Twin Cams have differing gear ratios is because of a two-tooth/nub reduction in the 2007 to 2008 rear-wheel pulley. The ratio for the 2009 Twin Cams reverts to the 2006 Dyna ratio (1.35 x 2.13 = 2.88 or 2.88:1) so that the engine turns 2.88 times per rotation of the rear wheel because the rear pulley increases from 66-nubs to 68-nubs.

4. My 2007 FLHXI 6-speed is featured on the cover of Volume II: *Performancing the Twin Cam.* When new, before performancing the engine, the bike and I suffered the same fate as when breaking in the 2006 FLHXI. The difference was the very low sub-zero temperatures. I knew the cold weather would allow me leeway in more speed. Once more, my friends began to leave me behind. I had to stay at close to 80 mph to catch up, but the rpm needle on the tachometer assured me I was within safe limits.
5. Soon after, I took my engine apart to hop it up. I was anxious to look at the cylinder walls and piston thrust surfaces to see if I was correct when going so fast during break-in. No damage had occurred whatsoever. The bike was breaking in just as Mother Harley would like. This is quite remarkable, due to the *gear ratios married to the Cruise Drive six-speed transmission and the TC96 engine in a match made in heaven.*

The above true life examples demonstrate how much the primary and secondary with the resultant final drive gear ratios have improved.

The modern Harley can now hold its own on any highway including most European ones, excepting the fast lane on the autobahn. I have ridden the autobahn over twenty years. Even the V-Rod would have trouble keeping up with sustained speed in the fast lane.

Performance is all about increased torque and horsepower. The third component, drive ratios, delivers this power in a way specific to the rider's needs and wants. Those who forget about or ignore primary, secondary, internal, and final drive ratios do so at their own peril. There is no quicker way to lose a race or have an uncomfortable touring motorcycle than with an unsuitable powerband for the intended purpose. Gear ratios are the forgotten part of the horsepower and torque equation for delivering usable power to the rear wheel.

Outside of the engine, gear ratios determine the powerband where peak horsepower develops and falls off. You as a rider want the powerband matched to the horsepower and torque of a particular engine and married to the motorcycle's function. Many mechanics and riders mismanage the powerband's effective range. They mistakenly engineer peak horsepower beyond or out of the normal rpm capability of the engine.

What's the point having peak power in the powerband at 6500 rpm when the engine may only be safe to take to 5500 rpm? Normal riding is, give or take 500 rpm, from 2000 to 4000 rpm and this is where the powerband should be functional.

Riders will want to alter the above general powerband range specifically to their riding styles. Those who ignore or do not understand primary, secondary, internal, and final drive ratios are at a big disadvantage. It is crucial to manage the power transferred back to the rear wheel in usable amounts relative to engine rpm, mph speed, and load on the bike.

It is a time-honored tradition for H-D riders to change sprocket/pulley sizing in order to affect overall drive ratios for their riding style or sometimes just for the flavor of the day. A concern with radical gear tooth changes resulting in lowering or raising an engine's rpm may take the engine out of its normal powerband speed. This may increase the probability of detonation under load and affects performance in specific area(s) if changed too much. For example, increasing a belt drive transmission pulley on a five-speed from the stock 32-teeth to a modest 34-tooth pulley will decrease engine rpm by around six percent.

Internal Transmission Ratios

Internal transmission gear ratios have two main purposes.

1. The first is obvious in that they transfer power back from the engine to the rear wheel when the clutch is engaged (lever out).
2. The second is to capitalize on the engine's powerband at varying rpm levels, speeds, and loads. The differing gears allow the rider to select a specific gear from four, five, or six choices depending on whether the transmission is a four- 5- or 6-speed. Thus, the rider is able to select a gear that is the best for the combination of rpm, mph, and the load or no load the bike is under at that time.

An internal gear ratio compares the number of times the clutch hub/mainshaft turns relative to one turn of the transmission pulley or sprocket, as the case may be, the higher the ratio, the lower the gear.

I quote BAKER Drivetrain for a compelling reason for the 1:1 final gear ratio, "Power flow through the transmission, the 1:1 gear is always the most efficient gear, typically 99+% efficient. Meaning, for every 100 ft/lbs of torque that goes into the transmission, 99 ft/lbs of torque comes out of the transmission and goes to the rear wheel. To compare, the sixth gear in an overdrive unit is around 92% efficient.

However, by going to a 1:1 sixth gear we lost the benefit of rpm reduction while cruising on the highway. We have 'overdriven' the primary drive to adjust the overall drive ratio by using a 28-tooth compensating sprocket in place of the stock 24/25-tooth sprocket. The result is a six-speed that is exactly, ratio-wise, like the (BAKER) six-speed overdrive (OD6)." [4]

The talented and innovative Bert Baker a former automotive transmission development engineer for one of the Big Three has created a primary ratio of 1.29 when compared with 1994 to 2006 five-speeds whose primary ratio is 1.44:1. The 1994 to 2006 five-speed Big Twins have a primary ratio of 1.44 engine rotations for one rotation of the clutch hub and the joined transmission mainshaft that the hub sits on by using a 25-tooth engine sprocket and a 36-tooth clutch hub sprocket.

Therefore, the BAKER DD6 has a primary ratio of 1.29 engine rotations for one rotation of the clutch hub and thus one rotation of the attached transmission mainshaft that the hub sits on by using a 28-tooth engine sprocket and a 36-tooth clutch hub sprocket. The 1.29 primary ratio calculates by dividing the 36-tooth clutch sprocket by the 28-tooth engine sprocket (36 ÷ 28 = 1.2857: rounds off to 1.29)

GEAR	COMPARING TRANSMISSION INTERNAL GEAR RATIOS							
	2005 H-D 1.00	**2006 DYNA 1.00**	**07-08 H-D 1.00**	**S&S 6-spd 1.00**	**BAKER DD6 1.00**	**BAKER [1] OD6-Z 0.86**	**RevTech 6-spd 0.893**	**Ultima 6-spd 0.86**
1	3.21	3.34	3.34	3.88	3.77	2.94	2.93	2.94
2	2.21	2.30	2.30	2.66	2.56	2.21	2.08	2.21
3	157	1.71	1.71	1.94	1.87	1.57	1.53	1.57
4	1.23	1.41	1.41	1.48	1.44	1.23	1.24	1.23
5	1.00	1.18	1.18	1.18	1.15	1.00	1.00	1.00
6	NA	1.00	1.00	1.00	1.00	0.86	0.8931	0.86
RPM	3227 @ 75mph	2951 @ 75mph	2859 @ 75mph	3043 @ 75mph	2879 @ 75mph	2776 @ 75mph	2883 @ 75mph	2776 @ 75mph

BAKER has two available first gear ratios with DD6 (3.77 or 3.45). The BAKER OD6 has three first-gear choices (3.21 or 2.94 or 2.82), two second-gear choices (2.21 or 2.08), and two sixth-gear choices (0.86 overdrive ratio: 2776 rpm @ 75mph: or 0.80 overdrive ratio: 2583 rpm @ 75mph).

[1] BAKER also has an overdrive six-speed called the R ratio (1st 2.75; 2nd 2.05; 3rd 1.55; 4th 1.18; 5th 1.00 and a sixth gear overdrive of 0.86)

Internal Transmission Ratio Formula

It is necessary to know the number of teeth on the mainshaft gear and its mating countershaft gear for the gear ratio we are going to calculate.

$$\frac{\text{Final Mainshaft drive gear teeth}}{\text{Final Countershaft drive gear teeth}} \times \frac{\text{Mainshaft speed gear teeth}}{\text{Countershaft speed gear teeth}}$$

The speed gear is the gear we are calculating the internal ratio for.
For example the internal transmission ratio for a 5-speed 1st gear is

$$\frac{41}{22} \times \frac{31}{18} = 3.21$$

The resultant figure 3.21 means that there are 3.21 revolutions of the clutch sprocket for one revolution of the transmission pulley in 1st gear. Direct drive 1:1 ratio in the final gear results in one revolution of the clutch sprocket for one revolution of the transmission pulley.

Performance is all about increased torque and horsepower. The third component, drive ratios, delivers power in a way specific to rider needs and wants.

Gear Ratios

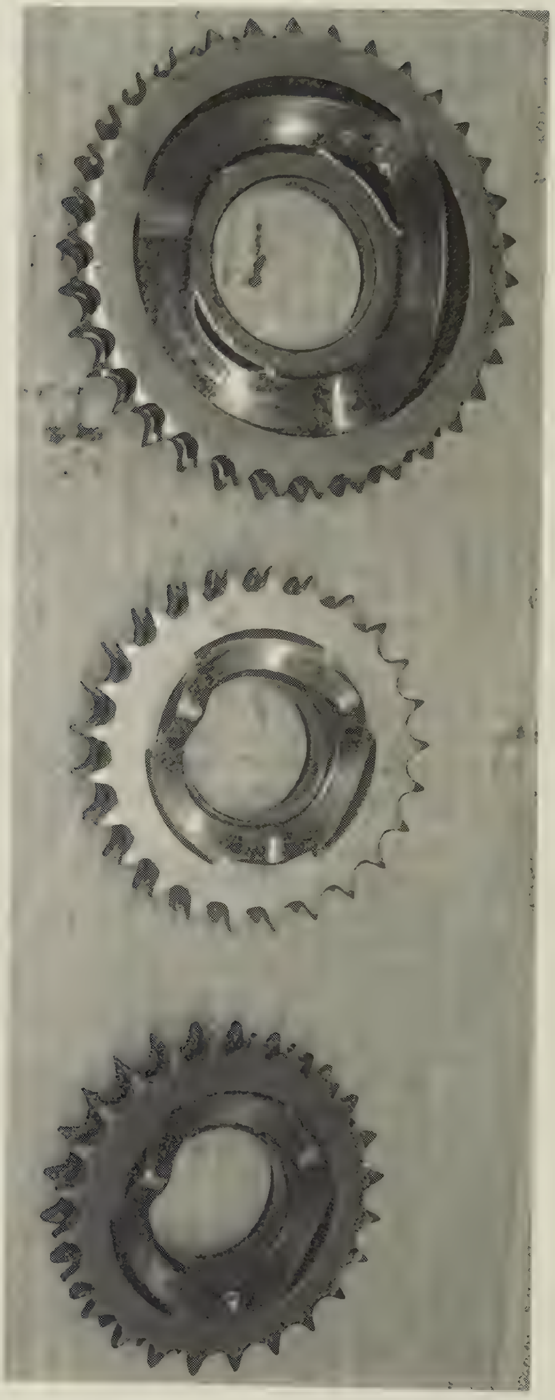
GEAR	2005 H-D	2006 Dyna	2007-08 H-D	S&S	BAKER
1	10.11	9.87	9.31	11.51	10.60/9.70
2	6.96	6.80	6.42	7.88	7.20
3	4.95	5.09	4.77	5.76	5.26
4	3.86	4.17	3.93	4.37	4.05
5	3.15	3.46	3.28	3.49	3.23
6	NA	2.88	2.79	2.97	2.81
RPM	@75mph 3227 rpm	@75mph 2951 rpm	@75mph 2859 rpm	@75mph 3043 rpm	@75mph 2879 rpm

S&S uses a 34-tooth transmission pulley with 70-tooth rear pulley.

The benefits of an overdrive 6th gear like that found in the .089 Screamin' Eagle and .8931 Rev-Tech transmissions eliminate the 1:1 ratio disadvantages of a higher rpm in sixth gear if using stock primary and secondary drive ratios. The overdrive aftermarket six-speeds, which are mostly a .089 ratio, also come in .086 and the radical .080 ratios that work well with more cubic inches but extra power is not necessary with the .089 ratios. Overdrive 6th final gear transmissions:

1. Still the same good initial take-off power and acceleration.
2. There is lower rpm and smoother highway riding in 6th gear.
3. Conserved highway fuel consumption.
4. My own experiences dictate the use of these .089 transmissions with performance engines and/or for bikes and their riders that do high-mile-per-day touring. Otherwise, there is no real need for an overdrive unless luxury is your game. The overdrive transmissions work best in 2006 and earlier Big Twins with stock or close to stock gearing in the primary and rear drives.

The direct drive 1:1 transmissions come into their own when overdriving the primary, as with 2006 Dyna Glides and 2007-to-present Big Twins or the BAKER DD6 that comes with a 28-tooth engine sprocket. All the transmissions are cool when used with their respective primary ratios.



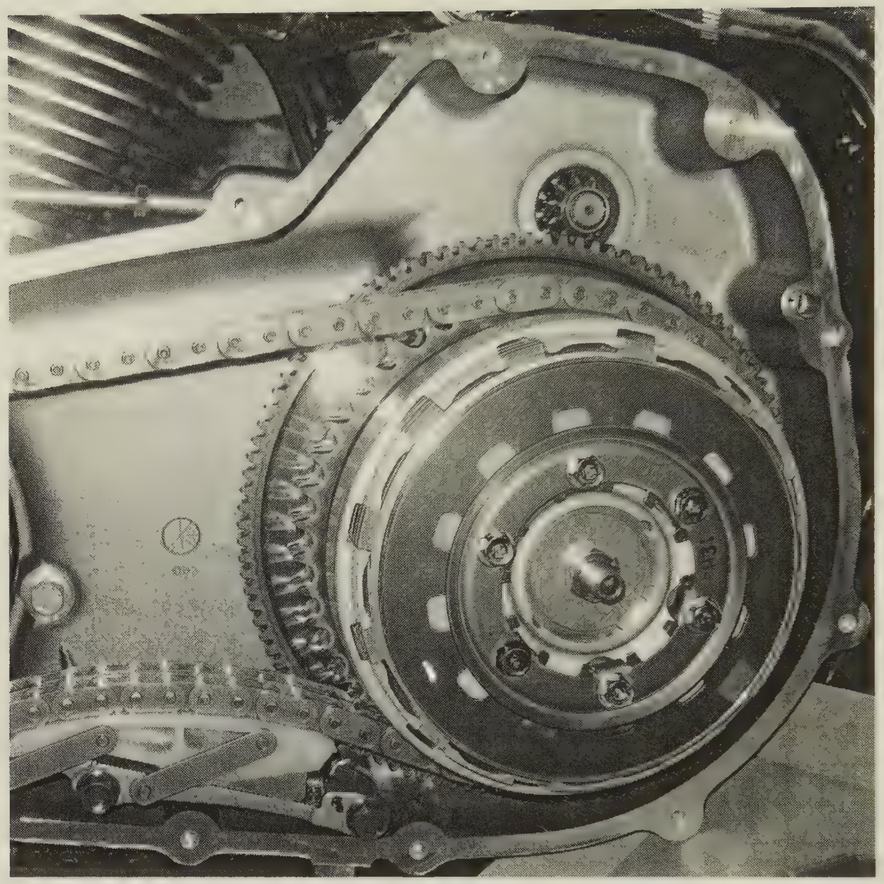
Comparing Big Twin Engine Sprockets - 1985 to Present

The top sprocket is the 34-tooth engine compensating sprocket (40320-06) introduced in the 2006 TC88 Dyna and carried over into all 2007-to-present TC96, TC103, and CVO 110 Big Twins. The middle 25-tooth compensator sprocket (40308-94) was used from 1994 to 2006 except the 2006 Dyna. The bottom 24-tooth sprocket (40265-89A) was used on 1985 to 1993 Big Twins. They all use the same ride-up, diaphragm spring power-absorbent cushioning ramp system. The three ramps mate with another mating ramped piece called a *sliding cam*. Sudden power surges from the engine are absorbed as the mating ramps ride up on each other controlled by the diaphragm compensator springs. The 2006 Dyna TC88 and the 2007-to-present TC96, TC103, and CVO 110 models have a supercharged primary gear ratio that complements the Cruise Drive 1:1 final drive six-speed transmission gear ratios. If there is a secret to the six-speed, this is it.

GEAR	**OVERALL GEAR RATIOS-DOMESTIC MODELS**							
	FLH	1999 EFI	2005 TC88	2006 Dyna	2007-08 TC96	2009-10 Touring	2010 Trike	2010 FXD/FXST
1	11.19	10.81	10.11	9.87	9.31	9.59	9.88	9.31
2	5.97	7.45	6.96	6.80	6.42	6.65	6.85	6.45
3	4.59	5.29	4.95	5.09	4.77	4.94	5.09	4.79
4	3.73	4.13	3.86	4.17	3.93	4.00	4.12	3.88
5	NA	3.37	3.15	3.46	3.28	3.41	3.51	3.31
6	NA	NA	NA	2.88	2.79	2.88	2.96	2.79

Overall gear ratios show the number of engine revolutions required to turn the rear wheel one 360-degree turn. In first gear a 2007 TC96 takes 9.31 engine revolutions to rotate the rear wheel once, while a 1999 TC88 takes 10.81 engine revolutions. Overall gear ratios take into account the internal transmission ratios with the primary and secondary gear ratios, while the final drive ratio is a simple multiplication of the primary ratio times the secondary ratio.

HDI (H-D International) models generally have taller gearing using smaller rear pulleys for better highway touring because of increased speed limits.



2006 TC88 Dyna and 2007-to-Present TC96, TC103, and CVO 110 Twin Cam Clutch

Pictured is the Twin Cam clutch for the 2006 TC88 Dyna and all 2007-to-present TC96, TC103, and CVO 110 models. The starter (jackshaft), pinion gear (31345-06) is at top right above the starter ring gear on the back of the clutch hub (37813-06A). This gear thrusts out to engage and turn the ring gear when the starter button is depressed. The clutch hub turns, rotating the front 34-tooth engine sprocket (40320-06) via the primary chain (40037-07 FLT, 40036-06 FXST/Dyna). The front sprocket sits on the end of the crank's sprocket (power) shaft. Therefore, the engine also turns over, allowing the ignition to fire the spark plugs to start the engine. The 46-tooth clutch hub sprocket moves inboard from behind the hub on previous models with the 2006 Dyna and all 2007- to-present Big Twins. The lighter gray (gold in real life color), clutch pressure plate depresses the larger dark gray clutch diaphragm spring (37882-06) to engage the 9-clutch plate fibers (37932-98) and 8-steels (37913-98) sitting inside the clutch hub. The center adjusting screw (37090-98A) locked by its jam nut (H-D 7848W) doubles as a clutch pushrod extending into the transmission mainshaft. It butts against the clutch release pushrod (37092-06), which is not shown that runs through the main shaft center to in turn butt against the rod assembly (37069-90) and its clutch throwout bearing (37312-75) in the right side transmission end cover (not shown). This mechanism is activated by the rider pulling in the clutch lever extending the inner clutch cable and a ramp-ball bearing system inside the transmission right cover. This pushes the clutch pushrods, which in turn pushes out the clutch diaphragm spring to release pressure on the clutch plates thus disengaging the clutch. The new automatic primary chain adjuster (39929-06A) is lower left, tensioning the primary chain. The clutch basket that holds the clutch plates changes in 2011 to accommodate a new narrower bearing necessitating a relocation of the snap ring groove. The new assembly will retrofit as a unit.

Connecting the Powertrain

The clutch, which sits on the primary side end of the transmission mainshaft, is necessary to connect and disconnect engine power to the transmission. When the clutch is disengaged, (clutch lever pulled in), the primary drive continues to turn but power does *not* transfer into the transmission via the input (mainshaft) shaft. The clutch plates separate (slipping) and power does not transfer through to the final drive.

As the clutch engages (clutch lever released), engine power transfers to the transmission input mainshaft for further gear reductions. This accomplishes when the internal diaphragm clutch-spring pressure plate locks the clutch plates together via friction. Torque then transfer to the rear wheel via the secondary ratios of the transmission output pulley that moves as one with the output mainshaft final gear; back to the rear wheel pulley moving as one with the wheel.

2007-2008 Rear Belt Tension Specifications

Model	Bike Position	Tension (belt deflection)
Softail Models		
FXST, FXSTC, FXSTF, FXSTB, FXSTS FLST, FLSTC, FLSTSC	Bike upright, rear wheel raised	11/16"-3/4"
Same models as above	On side stand no excess weight	9/16"-5/8"
FLSTN, FXSTD	Bike upright, rear wheel raised	5/16"- 3/8"
Same models as above	On side stand no excess weight	1/4"-5/16"
Dyna Models		
FXD, FXDWG, FXDC	Bike upright, rear wheel raised	1/2"-9/16"
Same models as above	On side stand no excess weight	5/16"- 3/8"
FXDL, FXDB	Bike upright, rear wheel raised	5/16"- 3/8"
Same models as above	On side stand no excess weight	1/4"-5/16"
Touring Models		
FLHT/C, FLHR/C, FLHTCU, FLTR	Bike upright, rear wheel raised Or on side stand no excess weight	3/8"-7/16"
FLHRS, FLHX	Bike upright, rear wheel raised Or on side stand no excess weight	1/4"-5/16"
Sportster Models		
XL883 STD, XL883R XL1200R	Bike upright, rear wheel raised Or on side stand no excess weight	9/16"-5/8"
XL883C, XL1200C XL883L, XL1200L	Bike upright, rear wheel raised Or on side stand no excess weight	1/4"-5/16"

There have been changes to tensions (belt deflection), and procedures to obtain correct tensions because of the new type of belt used. Your Harley should be at ambient temperature with the transmission in neutral. As always, check and adjust in the belt's tightest spot. Check tension at 10lbs pressure midpoint at the bottom of the lower belt. Harley-Davidson tool (H-D 35381A) will assist the inexperienced.

2009+ XN7 Rear Belt Tension Specifications

FLHX	Bike upright, rear wheel raised	1/4"-5/16"
All others	Bike upright, rear wheel raised	1/4"-7/16"

Clutch Plates

Until 1984, older Harley's used ten coiled clutch springs with a dry (oil-less), clutch pack to engage and disengage the clutch plates. Pressure rarely disperses evenly on these older clutch mechanisms. H-D wisely went to the diaphragm clutch spring and multi-clutch plate wet system from late 1984 until the present.

The earlier dry clutches had three or four thick clutch fiber plates, depending on year, separated by chunky steel plates. The newer clutch packs have six (1984-1989), eight (1990-1997), or nine (1998-to-present) thinner fiber plates separated by skinny steel plates.

Clutch Springs

The diaphragm clutch spring is a circular, conical disc made of spring steel. Pressure induced flattening of the diaphragm against the mating pressure plate provides the evenly dispersed spring pressure to engage the clutch pack bathed in primary chaincase oil. There are several reasons for wet clutch usage:

It is less costly and problem free, since the primary drive needs lubrication.

1. Debris from the wearing clutch fibers can be drained with the oil during servicing.
2. Oil keeps the clutch cool.
3. Wet diaphragm clutch plate pressure is more evenly applied than in previous dry clutches.
4. The increased number of wet clutch plates provides greater clutch surface contact, transferring through a higher percentage of the horsepower and torque.

Rear Belts

The 2006 Dyna Glide uses the thinnest belt (40015-00, 133 tooth) to date that continues on in use until 2008 transferring the power back to the rear wheel.

In 2009, a 1.000" wide carbon fiber belt takes over. Rear-drive belts have continually becoming thinner in width since their introduction decades ago. I must say I was nervous when looking at my 2007 belt never mind the 2009 setup but I will explain and alleviate any concerns further on.

Increasing Engine Size

The Factory made the change knowing that it's Screamin' Eagle big-bore kit 3 ¾" bore to 3 ⅞" bore would increase the 96c.i engine to 103 cubic inches. I will digress to say it is possible to use original TC96 cylinders and bore them out rather than purchase new cylinders. The 103 S.E. cylinders are bored out 96c.i cylinders.

Furthermore, the Factory is offering another kit to take the TC96 out to 110 cubes, so what gives with a thinner width drive belt only one-inch wide?

Torque Ratings

The Alpha (A) FLHT touring models engine torque is increased to 93 ft-lbs @ 3500 rpm, Dynas to 92 ft-lbs @ 3000 rpm, and the Beta (B) Softail models to 90 ft- lbs @ 2750 rpm. These reported measurements are at the engine and not the rear wheel where it counts.

Loss is anywhere between 12% and approximately 18% as the power transfers back. The higher losses result from such factors as chain and belt tensions, clutch adjustment, tire pressure, and motorcycle alignment, etc.

Touring models have bigger capacity mufflers than Dynas or Softails and, therefore, slightly more horsepower and torque. Beta Softail models have less torque than the Dynas because of internal loss of horsepower due to the energy required to drive the engine balancers. More torque requires a stronger Drivetrain

New Generation Belts

Original 1⅝"-wide belts used Aramid fibers colloquially known as the *bullet- proof* Kevlar. To demonstrate their strength, Harley published a picture of an FLHT hanging in the air supported by one thin Aramid fiber.

The X7N is the name for new final 1"-wide belt. It composes of the legendary second-generation carbon fiber. The X7N utilizes thicker fabric for increased tooth nub strength and durability. The polyurethane outer core body opposite the nubs is the same material used in previous width belts. The tensile cord in the middle comprises of the new carbon fiber. Space-age materials filtering down to everyday usage is decreasing previously necessary bulk in all types of applications in everyday life.

Changes to the TC96 Primary Chain Case System

The 2007-to-present Big Twin primary system also has many changes, most of them carried over from the 2006 Dyna. I have talked much about the new primary reduction ratios, but there are many other changes, such as the starter ring gear moving inboard on the outer clutch hub so that there is no longer a need for a starter motor extension jackshaft assembly.

This assembly, in various designs since its introduction on the first electric-start Harley, the 1965 Panhead 1200cc Big Twin has been around a long time. The starter solenoid kicks out the starter drive along the jackshaft to engage the ring gear. Now the 2006-present six-speed starters, based on the XL Sportster starter design connects directly to the inner primary housing in order to engage the now closer starter ring gear.

There is good news for starter removal, which is now possible without disassembly of other primary components.

There are big changes to the new 34-tooth engine compensator-sprocket parts. A compensator part of the engine sprocket originally included a big coil spring on both the Big Twin and the XL. In whatever form, a coil spring or a diaphragm one, the compensator absorbs energy shock from the engine back through the powertrain.

Since 1970, the spring portion of the compensator has consisted of a series of fixed and ⅛"-thick diaphragm spring plates. The 6-speed models have a 4-spring pack for both domestic and HDI models. The previous 4-speed and 5-speed compensator spring-pack was a separate part that fit between other mating components in front of the alternator adjacent to the outside of the engine casing inside the primary chaincase.

1. Now, the rotor portion of the alternator combines with the compensator as one part.
2. Further, it has multi-spline fitment over mating multi-splines on the engine output sprocket-shaft.
3. This unit was first introduced with the 2006 Dyna Glide.
4. The alternator rotor capacity increases in 2007.
5. The welded-together compensator-rotor rotates with the engine, spinning over the fixed stator to produce current to charge the battery.
6. The Softail and Dyna models upgrade with a new 40-amp alternator assembly. The rotor magnets increase to 12-magnetic units.
7. This stator and rotor assembly will retrofit to the 2006 Dyna models only.
8. In order to service as in replace the rotor, stator, or both on the rubbermount FLHT, removal of the inner primary was not necessary up until 2007. The inner primary must now be removed on all Twin Cams for service.

9. The new primary chain (40037-07 FLHT; 40036-06 FXST/Dyna) connects the engine sprocket to the clutch shell sprocket now moves to the outboard of the housing from its traditional inboard placement since 1965.
10. The clutch basket that holds the clutch plates changes in 2011 to accommodate a new narrower bearing necessitating a relocation of the snap ring groove. The new assembly will retrofit as a unit.
11. There is no longer a chain inspection cover on the outer primary to check primary chain tension. The primary adjustment is no longer a manual mechanical exercise but done with an automatic mechanical primary chain tensioner. I predict problems in this area in the future.
12. There is also a new primary-to-engine gasket and securing system bolting the inner primary to engine and transmission.

TC96 Primary Noise

I advise having a mechanic listen to your primary for adverse noise during regular service.

Noise may indicate adjustment pad wear; chain stretching, and other possible malfunctions. Do not confuse this sound with spur gear backlash noise from the transmission that amplifies through the primary cavity. Some mechanics feel that untoward backlash gear noise is not from the transmission or primary at all. They feel there are two noises.

The first is a fifth gear clatter that emanates from the transmission. Their solution is to use a heavier grade transmission fluid. This, in combination with riding at higher rpm in each gear will certainly lessen this noise.

1. They feel the second noise originates in the front cylinder, travels through the primary and into the transmission.

This conclusion derives after eliminating other possible causes such as there is sufficient oil pressure; compensator nut torque is within specifications; compensator springs are tight; other primary components are all within specifications, and, finally, the transmission gears themselves are checked.

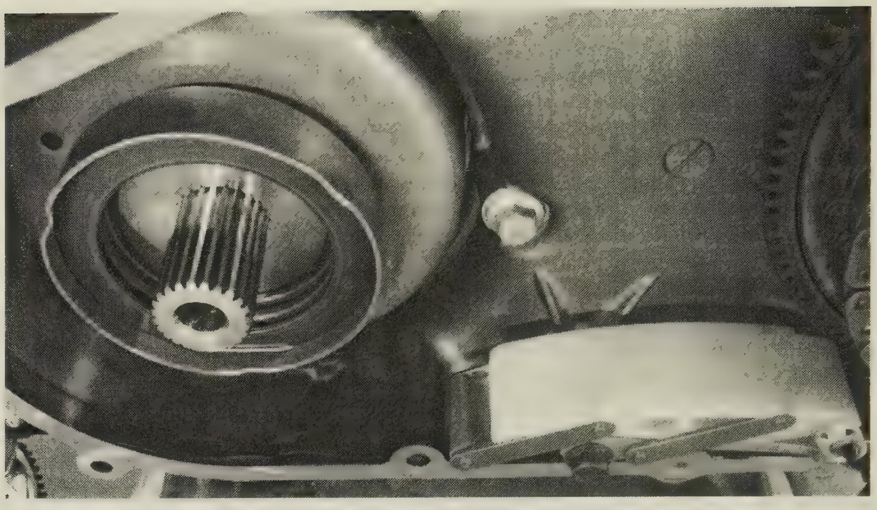
Finally, swapping a fifth-gear clattering transmission into a motorcycle that did not have noise issues had a very interesting and surprising result. The noise disappeared or, more correctly, did not follow the transmission into the quiet bike, leading one to believe that it originates elsewhere. This led to the conclusion that the noise emanates from the front cylinder. The theory is that shock load travels from the cylinder into the new echo chamber primary and on into the transmission making the 6-speed the innocent villain.

This may well occur on some bikes but indicates a perhaps more serious problem such as piston slap. The best-case scenario involves detonation noise, although detonation -- known as the great engine destroyer -- is never good.

To continue, sometimes replacing a noisy transmission with another had mixed results. Sometimes the noise disappeared and sometimes it did not. This leads me to conclude that while there are noises emanating from some engines and transferring to other components, there is still a problematic noise in some transmissions. In short, there may well be different noises blamed for the same cause. I will discuss this theory more as I proceed.

There is a cure or Band-Aid, you are the judge, for touring models later in the chapter under *The IDS Fix or is that an Enhancement?*

Switching from SYN3 in the transmission to semi-synthetic 80-90 hypoid-gear-oil will definitely help in some cases. The indicator of wear can be isolated over time by observing drained fluids, for the presence of debris in the fluid whether they be engine, primary, or transmission oils. Always observe drained oil for untoward particulate.



2006 TC88 Dyna and 2007 Softail-Dyna TC96 Twin Cam Stripped Primary

Pictured are the 2006 TC88 Dyna and 2007-to-present Softail/ Dyna TC96 Twin Cam inner primary chaincase (60777-07A black wrinkle) with the front sprocket and some compensator ramp parts removed. The 24-splined shaft is the crank or flywheel sprocket shaft, also known as the power shaft that extends through the engine case into the primary chaincase. The 24-multi-splines replace the ten 1/8"-wide splines on 1956-2006 (except 2006 Dyna) sprocket shafts. Sitting on the sprocket shaft is the alternator rotor-compensator one-piece package (40356-07). This two-into-one component was two separate parts on all previous models dating back to 1970. The four compensator diaphragm springs absorb engine shock as power transfers back through the clutch and transmission. There is an undisclosed specification from the engineers at the Motor Company. The compensator spring assembly on 2008 to 2010 (one piece with the rotor) should measure no less than 0.670" from the top spring to the bottom of the groove. Anything less than this specification will make extra noise in the primary. The alternator rotor has magnets in its inner circumference; it rotates around the fixed stator inside the rotor (not visible), in order to charge the battery. Also shown is the new automatic primary chain adjustor (39929-06A).

Primary and Transmission Fluid Requirements

The TC96 FLHT touring models in 2007 require 45 oz of primary fluid if dry and 38 oz for wet capacity. This means:

1. A drained FLHT primary requires the wet fill capacity because there is residue oil left inside the casings coating the internal parts.
2. Therefore, use the dry capacity fill when removal of the primaries is necessary for major service, such as alternator replacement. I am assuming the parts are clean. At least I hope they are clean. Consider this situation dry.
3. Softails and Dynas have the same fill primary requirements of 32 oz for both wet capacity and dry capacity. I know this does not make sense.
4. Primary service intervals now require servicing every 10,000 miles (16,000km), a doubling of the 2006 and earlier interval, of 5,000 miles (8,000km).
5. While we are at it, the 2007 transmission fluid-servicing interval has doubled, increasing the change interval to 20,000 miles (32,000km.) from the previous interval of 10,000 miles (16,000km).
6. Also, there is a new double-row-output bearing (H-D 8967) that most would call in more understandable language the sixth-gear mainshaft-transmission case bearing.

Structural Transmission Changes

Up until the 2006 six-speed, there was a separate sprocket shaft spacer (33344-94) to position the pulley in the correct place on the predecessor 5th gear in five-speeds and the 4th gear spacer (35079-82A) on the four-speeds. This spacer now incorporates with the case bearing (H-D 8967). There is now one combination part as opposed to two former ones.

The redesigned 2006 and later Dyna transmission casing eliminates external oil lines and features a new interface gasket with the engine.

Transmission Nut Right-Hand Thread

The big change here for longtime wrenches and mechanics is the transmission pulley nut (39241-06) known in Harleyese as the output sprocket, now has a right hand thread. This nut has been a left-hand thread going back well over a half century. There is not one threaded nut that has caused more confusion, frustration, broken parts, and bruised knuckles than the left-hand tranny nut. Those who have worked on Big Twins for any length of time that learn by trial and error, neglecting to read, will face some trying moments with this simple change.

One area the Factory has been very aggressive in since 1984 is attempting to choke off the aftermarket with their in-house motorcycle improvements, which are great, but maybe a little too late, since development generally, bases on existing aftermarket popularity.

Then, sometimes, perhaps H-D moves a little too fast.

Best Bang for the Buck: the 2006 Dyna Glide

The first use of a Factory OEM 6-speed transmission occurred with the 2006 Dyna models while all other model lines that year were still the traditional 5-speeds. However, the 2006 Dyna FXD became the best –bang-for-the-buck Harley on the market. The only better value Harley-Davidson to come along since then is possibly the base model 2007 EFI rubbermount XL.

A Cloud of Doubt

The 2006 Dyna Glide lived with nervous suspicion for 2006 regarding its powertrain, including the new transmission. Customers had to bring it in for accelerated service intervals while the service reps looked at a suspect bearing. More time is required to see if this evolves into something more, as an accumulation of miles ridden will yea or nay this most improved model of 2006. As time went on, H-D resolved the problem.

I asked for and received a copy of service addendum. It states that Harley is monitoring the issue and has revised the service interval from 20,000 miles down to 5,000 miles. The gist of this being that the consumer pays for a service and inspection every 5000 miles, and then Harley replaces the bearing every 15,000 miles at no charge to the motorcycle owner.

Now, once again the much-heralded 2007 Big Twin TC96 is under a cloud of suspicion surrounding the 6-speed transmission for different noise-related reasons.

Speedometer

There are many convenience components on other bikes, such as the Gold Wing, that their advocates take for granted.

H-D has put a 6-speed indicator light in the speedometer face that is very cool. Now the uninitiated can tell when they are in their final gear with a glance. For me, I do not need it, but I like it.

Six-Speed Noise

Consumer Complaints

Complainants are expressing considerable concern over different noises emanating from the 2007 gearbox in some gears. According to the Factory, in attempting to allay the fears of its new Big Twin purchasers, the different sounds are nothing more than from the use of some different types of gears *designed to make the transmission quieter.* Detractors are saying that the new gears are supposed to be quieter rather than producing the clatter offending their ears.

Harley-Davidson first use of curved helical gears that engage each other fulltime eliminating straight-gear backlash was in the V-Rod. Helical gear successful usage follows in the 2006 Dyna, Sportster, and Buell transmissions.

The traditional straight spur- type gears have been used exclusively forever in Harley-Davidson transmissions up until the 2006 Dyna Glide. Spur-type gears are still used on 1st and 5th gears in the 2007 to 2009 Twin Cam transmission and the 2006 Dyna. Helical gears are used on 2nd, 3rd, and 4th gears with a 1:1 ratio direct drive helical 6th gear.

Spur gears use conventional, non-angled, gear teeth to transmit power. They have differing amounts of backlash defined as clearance between mating teeth in order to operate freely. The amount of backlash depends on manufacturing techniques. *Backlash* is a descriptive term initiated by teeth engagement that produces noise. It may produce a rattling noise where lots of backlash is present with initial engagement. If backlash reduces too much a whining noise may also occur as the gears engage tightly when heated by transmission operation.

Backlash Noise

Backlash noise is greatest when first taking off or when changing gears. The gears can move back and forth when not under constant pressure, as when under load.

The transmission housing on Twin Cams is definitely different from the Evolution and other predecessor transmissions. The Twin Cam transmission is designed to attach with and hug the engine cases in order to produce rigidity. It forms one with the engine casings as they are securely bolted together to provide symbiotic support and exponentially greater strength than if separated as on earlier models. Previous models depend on the primary chaincase to provide structural strength and rigidity. This new system is so strong that the primaries while an added benefit are not necessary for this support function anymore., While the primaries lend structural support on Twin Cams, their main purpose is to enclose the inside primary drive components in a constant lubricating and cooling oil bath free from outside dirt.

The transmission gears as well as the engine's cams are heat-treated in the traditional oven-quench format. This heat-treating is via modern wave technology where in a mere twenty seconds these treated parts become red hot. They are then quenched (cooled) to produce a .040 thickness of the desired hardness.

H-D uses a newer technology for gear fitment. The straight-cut spur gears have previously fit loosely and clattered away as they interacted. You may have read about the full contact-ratio spur gears in Harley promotional literature whereby machined gears roll into each other, utilizing the whole contact area available. This disperses pressure and produces less noise. Then the gears are heat-treated to develop hardness. This causes some distortion to the machined surfaces, producing high points that again result in noise.

Machining the gears again with the new technology occurs after the heat-treating process without damage. The result is a quieter spur gear that engages with its mating gear more fully than ever before for further noise reduction caused by backlash.

EPA -dictated noise reduction regulations drive all of these changes. This is why the noise complaints about the mostly helical–cut-gear new 6-speeds are so disturbing. These helical gears are supposed to be quieter and are the main reason Harley has employed their use.

I have had many noise complaints from a network of technical buddies whose opinions and teachings I have learned to respect. Also evidencing the problem is the fact that Harley-Davidson has addressed these concerns in publications like their own fall edition of the 2006 *Enthusiast.*

However, I have not heard the reported noises myself. I rode my new 2007 FLHXI in late 2006 on two occasions for a total of 150 miles in zero- degree weather as the wind chill drove the effective temperatures down much further at highway speeds. The air-temperature gauge in the faring never went above 38^0 Fahrenheit.

The transmission shifted smoothly and positively with no noise whatsoever emanating to my attentive ear although my full-face helmet covered them. I mentioned this to a 2007 Ultra owner who also happens to be an engineer living in a warmer clime. He was exasperated that I could not hear any noise from my 6-speed in the cold weather and warned me I wouldn't be happy when the Canadian summer came and the transmission would heat to normal riding temperatures. I still own the 2007 FLHXI in 2011 that graces the cover of Volume II: *Performancing the Twin Cam*...still no noise.

The controversy continues about noise emanating from the new H-D 6-speeds although they were designed to be quieter than the previous all-spur gear Harley transmissions.

The Cruise Drive

The Harley-Davidson six-speed, named the Cruise Drive, involved two phases of development.

The introduction of the six-speed in the 2006 Dyna with its many changes included the use of helical-cut gears. After monitoring the newly pioneered helical gears in the 2006

Dyna Glide transmissions, H-D decided their success merited phase two. This was the full introduction of the 6-speed into all 2007 TC96 Twin Cams.

It is essentially the same transmission as in the 2006 Dyna, although the case housings for the FLHT and Softail models are necessarily different because of distinct frame and/or primary casing designs.

Upgrading the Detent Arm

The one corrected glitch in 2006 was a recall for the Dyna transmission shift-detent arm and roller with mating spring. The detent arm and related parts are crucial to easy and positive gear shifting in the transmission. The new 2007-detent assembly (33409-06B + spring 33389-06) retrofits to post-recall 2006 Dynas and sells as a kit for the 2006 six-speeds. This new detent assembly is an attempt by the Factory to make shifting easier and give a feel-good impression with the new transmission. It does feel better relative to what went before.

Negative Inertial and Momentum Forces

However, there are some negative effects deriving from the physics principles of inertia and momentum since there is a huge rotating mass that must turn whenever the mainshaft turns.

The 1-piece 1st-through-4th gears combining with the mainshaft are a lot of weight and mass to move from a stop (inertia).

1. The weight is also a lot to stop when already moving (momentum).
2. If the gears were all independent of each other and the mainshaft, there would be a lot less work and expended energy. As Bert Baker says, "I believe that Harley's 1-piece mainshaft with 1st, 2nd, 3rd, and 4th gears as an integral part is a big shortcoming with the Cruise Drive design. It is responsible for clunky audible shifting because it is desirable to have the inertia of the mainshaft/clutch hub as low as possible." [5]

Clutch Cable Ease

Reduced clutch cable effort follows the design change in the 2006 Dynas. The reduced-effort clutch lever enables a 10% reduction for Softails and 7% for FLHT touring models. Let's not leave the Sportster out, which has an 8% reduction.

The Clutch Interlock Switch

There is a new clutch interlock switch specifically designed for new-rider safety, something get-up-and-go, experienced riders have mechanically been doing forever. Many of us leave the bike in 1st gear when stopped. We turn the ignition on, pull in the clutch lever to disengage the clutch, and press the starter button and off we go. This interlock button switch activates via the clutch lever position. It is located in the clutch-lever handlebar control. It is just behind an appendage of the clutch lever itself beside the clutch-cable attachment pin to the handlebar control piece.

In the sometimes confusing Harley vernacular, the Factory describes this as an "or" function with the neutral switch. The interlock switch will verify if the bike is in neutral or not before permitting starting. If in neutral, the starter will function when the e-start button is pushed in. If not in neutral, the bike will not start until the clutch lever is pulled in (disengaged). However, this is not what is attracting consumer attention.

More Noise Complaints

Noise complaints, rightly or wrongly, are faulting the mostly helical-cut gear H-D 6-speeds. However:

The full-contact helical gears design is quieter.

1. Helical gears are stronger with more load-carrying capability than spur gears.
2. Further strengthening the gears is an increase in diameter size.
3. There are also some larger internal transmission bearings and a stronger casing.
4. H-D has also been very progressive in machining gears to closer tolerances to reduce backlash noise.
5. Maintenance and the time between service intervals are extended because of all these improvements.

It is true that the H-D helical-cut 2nd through 4th gears smooth and quieten the transmission. The problem, whether perceptual or real, may have its theoretical basis in the side thrust perpetrated by helical gears angled in the same direction. Side thrust may be interfering with the spur gear in fifth, amplifying its noisier backlash characteristic.

The traditional spur gears used in H-D transmissions are more than capable of handling the loads and power transferred through them. However, who can argue with stronger?

The helical gears eliminate the backlash noise prevalent with traditional spur straight-cut gears used in predecessor Harley transmissions. Evidencing the problem is the fact that Harley-Davidson's Ben Vandenhoeven, plus engineers and service advisers have addressed these concerns in publications like the *Enthusiast* in the fall 2006 edition.

The question becomes; are these sounds perceptually worse because they are different from traditional H-D transmission backlash noise, or is there a mechanical problem that needs correction?

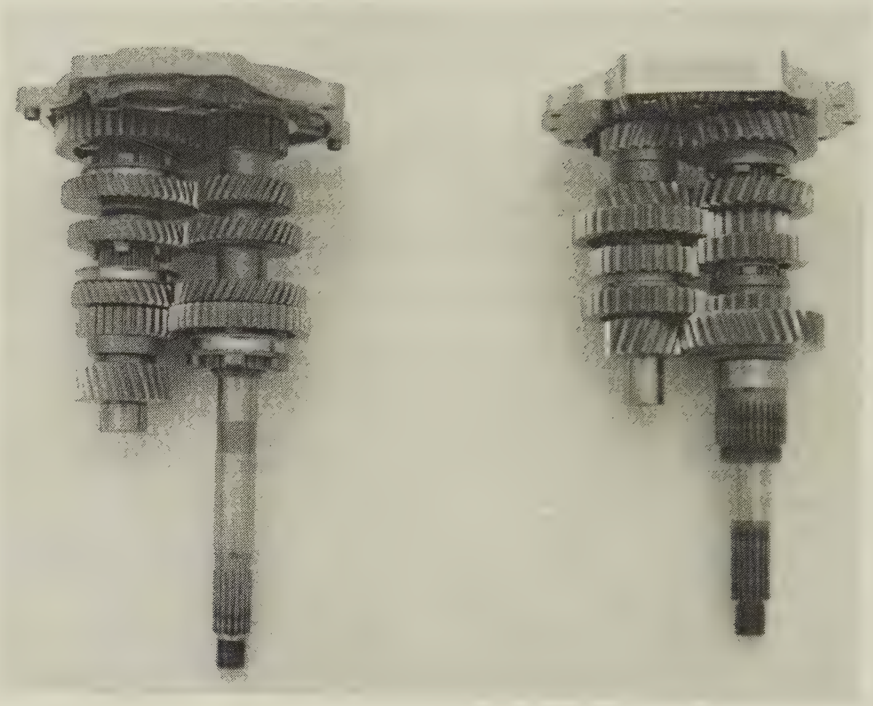
The advantage for manufacturers in using spur-type gears is that they are durable and inexpensive to manufacture. However, the space between mating spur gear teeth allow clatter, which occurs when not under load. However, the gear teeth force together to work (under load), in unison, eliminating the clatter when they are called upon to transfer power through the transmission to the drive pulley.

Helical and Spur Gears

Noise emissions is the primary reason for many changes to your Harley over the years, from the elimination of rear chains in favor of enclosed, oil-bathed ones to the evolved present belt drive. Eliminating the supposedly noisier timing chest-gear-driven Evolution cam with two silent chain-driven cams necessitated the development of the Twin Cam. Now there is the introduction of quieter transmission helical gears in the Twin Cam 6-speeds, Sportsters, and Buell's.

A helical gear drive uses angled gear teeth that eliminate backlash noise since more than one tooth engages at all times. The angular sliding engagement of helical gears results in a constant meshing of gears. However, this angular engagement also causes a side thrust. The H-D helical transmission gears will create side thrust in one direction. Herein may lay a problem because some speculate that this side thrust necessitated the need for the use of a 5th spur gear in the Cruise Drive.

The friction resulting from this side thrust can absorb a small amount of engine power. This is called *internal frictional loss of horsepower.* However, the amount is so small that most are not concerned about this on a street bike.



Comparing H-D Cruise Drive and BAKER Drivetrain 6-speed Transmissions

On the left is the 2006 Dyna/ 2007 to 2009 TC96 and CVO 110 Harley-Davidson Cruise Drive 6-speed transmission with the BAKER DD6 (Direct Drive) 6-speed on the right. Both transmissions have a 1:1 gear ratio in 6th gear. Neither has an overdrive final gear. Both supercharge the primary sprocket ratios giving the feel of an overdrive. They both use quieter helical-cut gear sets in combination with straight-cut gear sets. The comparison between the two ends here. The new H-D Cruise Drive is criticized for being noisy, especially in 5th gear. I feel this noise amplifies through the primary acting as an echo chamber. The H-D mainshaft (the longer shaft) has 1st through 4th gears integral as one piece. The one-piece shaft and gears is a lot of weight and mass to move from a stop (inertia), and a lot to stop when already moving (momentum). If the gears were all independent of each other and the mainshaft like in the BAKER DD6, there would be a lot less work and energy expended. As Bert Baker says, "It is responsible for clunky audible shifting because it is desirable to have the inertia of the mainshaft/clutch hub as low as possible." [6] Furthermore, the H-D countershaft is integral with countershaft 5th spur gear and 6th helical-cut gear. When one rotates, four must rotate, including the mating gears on the mainshaft. The H-D 5th gear is the one cited by many as generating the noise. Therefore, the noisier 5th spur gears drag along, rattling away for the ride when the transmission shifts into the quieter helical sixth. There will also be a torque transfer loss because there does not need to be four gears driving in 6th gear in the H-D transmission, instead of two as in the BAKER DD6. Then Bert says, "There is also a measure of torque loss for the entire transmission while riding in sixth gear. This is due to the 1-piece structure of the mainshaft, with 1st to 4th gears being part of the 1-piece shaft. There is parasitic power loss to turn this very heavy shaft, which generates a great deal of centrifugal force. This bulky shaft design works to detract from the torque gains of utilizing a 1:1 6th gear configuration as well as making it shift like a tractor." [7]

The usage of helical gears is dependent on manufacturing expense budgeting, motorcycle use, acceptable gear noise limits, with miniscule power loss concerns coming in a distant fourth. Therefore, I repeat the obvious question, if helical gears are quieter than spur gears then why are there so many noise complaints? Defenders say that these noises are not loud at all but perceptual in nature as they are indeed different. Simply, Harley riders are not used to them yet. At this point, no one is saying the H-D 6-speed transmissions are going to blow up because of the noise. What are the complaints? Some are:

1. There is 6th-gear chatter at light throttle cruise, 55 mph to 65 mph that emanates from either the transmission or the primary.
2. Everything else about the new primary chaincase design is noisy. It is almost a bang sound as the engine starts and the clutch makes a clack sound as you bump the friction point with the lever.
3. And, of course, there is the 5th-gear clatter when engaged.

Engine Lugging

I nervously suggested to this exasperated email buddy who is an experienced longtime rider with exceptional technical skills that perhaps his not being used to an extra gear meant that he may have been *lugging* his new ride.

Lugging refers to not going fast enough in a gear. Lugging produces rapid wear by the engine working too hard. The engine has difficulty running in a too high a gear.

1. Symptoms include pinging (detonation), surging, and lumpy riding conditions.

Despite turning the throttle, the rpm's will climb slowly in a lugging situation as the overworked engine will only gain speed faster as it approaches its comfort zone. This is the *wrong* way to exit a lugging situation. Many new riders feel that they are being gentle with their new ride by staying in higher gears at lower speeds. Quite the contrary; they damage their engines!

Downshifting at least one gear always cures lugging. For example, if the rider is lugging the engine in 6th gear, the fix is to downshift into fifth. If downshifting does not fully clear up the lugging then a further downshift to 4th is in order.

It is a good thing my friend and I were conversing by e-mail. He was insulted and informed me clearly that he was not lugging the bike. I knew but had to ask.

- A reader related annoyance is that "the straight-cut fifth gear sounds bad, but most annoying is the chatter sound in sixth while not under load. The chatter goes away when you load it with either acceleration or deceleration".

- Another one of my *American Iron* readers and avid H-D fanatic says, "The ones I've been on all sound identical. Harley says it's normal and do not intend to do anything about it. That is a very shortsighted attitude. I know five people who have postponed new purchases until it is resolved. Sounds like AMF is running H-D again!"

That last comment is a little unfair, spoken in frustration. The much-maligned AMF introduced modern manufacturing techniques to the antiquated company and allowed it to survive until current management took over and made Harley-Davidson the darling of American manufacturing. In Volume III: *The Evolution: 1984 to 2000* and Volume VI: *The Shovelhead: 1966 to 1985,* I investigate AMF and lay some blame like increasing production without sufficient quality control where it belongs. However, AMF comes out looking pretty good in laying the groundwork for future success. After all, the Evolution motor, the 5-speed transmission and a bunch of other good stuff was initially developed and designed by AMF.

Lugging in 6th Gear is Common!

Obeying a 55 mph or a 60 mph speed limit on the highway is annoying with the Cruise Drive gear ratios. There is no need for a 6th gear in this situation. As a result, lugging in 6th gear is common.

Seventy miles an hour was a sweet spot for my 2006 and earlier Twin Cams on nearby 60 mph highways. The police in my jurisdiction tolerate this but not much more. Eighty miles per hour seems to be the new norm for my particular riding style in 6th gear on my 2007 FLHXI. The police do not tolerate this speed. Again, I must consciously monitor my pace. This is bothersome but when I start to daydream I begin to speed…until I come back to reality.

A Gear Modification Cure

The venerable BAKER Drivetrain has once again come to the rescue. Their cure will allow increased off-the-line response with more torque. As well, increased torque will affect performance positively throughout the rpm range. Furthermore, use of 6th gear at lower speeds without lugging is a big benefit of the two new smaller transmission pulleys developed by BAKER Drivetrain.

The stock 2006 Dyna and all 2007 Twin Cams use a 32-tooth transmission pulley (40659-06), the same size as predecessor Twin Cams and Evolutions going back to 1994 (40250-94C). However, the pulleys are not interchangeable. BAKER claims rear wheel torque increases 7% with their 30-tooth pulley and by 3% with their 31-tooth one when used with Harley-Davidson's Cruise Drive 6-speed transmission.

- A BAKER 2¼" special pulley nut socket (94660-07BD) is required for installation.
- The smaller 30-tooth and 31-tooth pulleys also need a belt with one-less tooth than stock.

H-D Response to Lugging

Harley-Davidson responds to customer's lugging the new Twin Cam 6-speeds in Service Bulletin M-1186 on November 20, 2006, titled ECM CALIBRATION UPGRADE FOR 2007 BIG TWINS (PRODUCT PROGRAM 0903).

Lugging is a rider-induced engine problem exacerbated by the new supercharged gear ratios in combination with a 6-speed transmission in combination with new riders who are overly cautious in riding their motorcycles. Therefore, they mistakenly ride in a lower rpm range in too high a gear thus overloading the engine. Lugging makes the engine work outside its comfort zone resulting in agonizing torque shock loads emanating from the engine and down the powertrain. H-D is particularly concerned with grabbing a handful of throttle under 1500 rpm. Well, I feel there is nothing wrong with hard acceleration in first gear under 1500 rpm with a warm engine that is broken in. However, if doing this from a stop or slow crawl in second gear, then the engine becomes overtaxed. Furthermore, doing this hard acceleration under 1500 rpm from a slow speed in third or higher gears will injure the engine over time. Lugging can happen in any gear and at any conservative speed during low and mid rpm ranges with hard acceleration if not starting at a high enough speed.

Harley attempts to address the problem of customer lugging with an ECM calibration upgrade that smoothes the torque curve in order to assuage high shock loading out the sprocket shaft and down the powertrain. This recalibration is already done on the assembly line after early November 2006. Production of next year models generally begins in July of the previous year. Therefore any 2007 TC96, CVO 110 and police specific Twin Cams built before early-November 2006 are eligible for this ECM recalibration upgrade.

Any H-D dealer can enter your motorcycle VIN (serial number) on www.h-dnet.com, which is inaccessible to the public to see if your motorcycle is affected. If so, the recalibration is free for as long as the bike is under H-D warranty.

Are the Deaf Evaluating the Noise?

Another comment was directed point blank at me and other tech writers. "I haven't seen a word in print about this, and it's hard to believe that there are that many deaf people writing new product evaluation articles." One more: "If we do not all start making some noise about *their* noise, their attitude toward this defective product won't change. H-D is a large advertiser in *American Iron Magazine* so you may have your hands tied."

True, some writers and magazines will print ridiculous claims. This is for the sale of an advertisement and therefore a paycheck. *American Iron* is not one of them.

Writers such as me have an unbending love for riding Harley-Davidson's and have done so for all our adult lives.

- Writing only provides for a subsistence-level existence, and most of us earn our main incomes from other related mechanical endeavors.
- Writing for the pleasure of expression, creativity, and educating limits corrupt practices.

In fairness, much of the northern U.S. and Canada enters autumn and winter soon after new model introductions so there is not a lot of time for many of us to evaluate certain conditions that may require extensive riding. Many of us including myself do not get the offer of a new bike to ride for evaluation purposes, and how could we all? The last time I evaluated new Harley's were six different 1999 models in late 1998.

I also think I may have worn out my welcome with the Factory by frank discussions of their products over time.

I opined to transmission expert Bert Baker that the noise complaints must originate with the change from second to fourth helical-cut gears to the fifth's backlash- prone spur gears. This fountain of information replied; "Yes, but the cause of the backlash rattles felt in fifth and sixth gears at low rpm can be attributed to multiple additional factors as well, with the primary drive system acting as a sound amplifier." [8] Now we were getting somewhere, but we need some more background information before we figure out the problems.

TC96 Performance

There is one indisputable and coordinated marriage of components that Harley-Davidson got very right on the 2007-to-present Big Twins.

First, through, dynamometer tests in both Canada and the U.S.A. have demonstrated that the new TC96 models have about the same horsepower as a stock Twin Cam 88! I am not happy with this. Some performance builders are blaming the overdriven primary ratio.

I am sure one reason is the use of anemic flowing heads on both cubic-inch displacement bikes. I have no idea why the valves have remained the same size either as cubic inches increased. How can a head that flows less than the predecessor Evolution head that serves an 80-cubic inch displacement engine be satisfactory for a TC88 engine or upgraded big bore-95? Although the 96" heads very much base on the TC88 ones, I have taken my 2007 apart and can relate that Harley-Davidson has made some improvements to the heads, which I will describe in detail in Chapter XII: The 2007-to-Present TC96 Engine.

I will now relate a positive aspect of the TC96. The torque on the TC96 is much more than that on the TC88. Horsepower…smorsepower; who cares when there is a lot more torque? Torque is real power. Horsepower is merely an arbitrary mathematical concept that I will explore in depth in Volume II: *Performancing the Twin Cam.*

1. The FLHT TC96A touring models engine torque increases to 93 ft-lbs at 3500 rpm compared with TC88 models of 85 ft-lbs at 3000 rpm.
2. The 2007 TC96 Dyna Glide increases to 92 ft-lbs at 3000 rpm compared with TC88 models of 85 ft-lbs at 3000 rpm.
3. The TC96B Softail models increase to 90 ft-lbs at 2750 rpm compared with TC88B models of 85 ft-lbs at 3000 rpm.

This increase in torque combined with the superb matching of the primary, secondary and final gear ratios along with the 6-speed transmission makes for a very much faster motorcycle. All internal gear ratios are married in harmony with the increased engine displacement and especially the torque increase.

This results in very much improved acceleration characteristics, sometimes called a *roll-on*. Roll-ons in each gear improve with the TC96 because of the superior gear transition.

H-D transmissions traditionally…and in my experience…can have awkward shift points. Gear shifting may be too close together or too far apart. Hence, the need for close ratio gear sets first introduced by John Andrews decades ago. The Cruise Drive 6-speed moderates these shift points, thus eliminating any big gaps between gears.

A further bonus is a better, more comfortable ride because of substantially lowered engine rpm. At 75 mph, 6th gear reduces rpm by a whopping 11%, from about 3225 rpm to 2850 rpm. The impact of this reduction on a long trip is wonderful.

Of course, the reason for this decrease in rpm in sixth gear …when the ratio is 1:1, the same as the 1:1 ratio in the 5th and final gear of the 5-speeds…is the extraordinary increase in primary sprocket sizes.

Torque Transfer and Ratings

Therefore, three advantages of the Cruise Drive are matching the bigger engine with its increased torque with the gearing within both the transmission and the outside powertrain.

The increase in gear strength due to helical gear usage.

1. The torque capability of the Cruise Drive is almost 30% higher than the 5-speed transmission. This is due to the wider diameter gears.
2. The six-speed primary and secondary gearing results in a higher final drive ratio.

The rider enjoys a seat-of-the-pants experience on a motorcycle faster than its predecessors. The final drive ratio for the 2007TC96 is 2.79:1, compared with 3.15:1 for 2006 five-speeds. Therefore, the engine turns 2.79 times for one rear wheel rotation in 2007 compared with 3.15 times in 2006.

The New Frontier: Transmission Gear Torque Capacity

An increase in torque capacity for new transmissions seems to be a next frontier. BAKER Drivetrain has introduced the TB6 (TB stands for torque box).

Bert Baker claims the TB6 rating is for 250lbs of torque with larger gears and a new case design.

1. Harley-Davidson's new 6-speed is rated at 125lbs.
2. The H-D Cruise Drive torque has a 28% increase over the five-speed. Therefore, the torque rating of the five-speed is approximately 98lbs.
3. The five-speed seems puny in this ratings game, but it has proved to be very strong and durable since its inception in 1980. Torque rating increases are primarily due to wider-diameter gears.

The Cruise Drive's mainshaft gear center distance to the mating countershaft gear center is 2.8".

1. The H-D 5-speed has a center distance of 2.5".
2. The BAKER TB6 uses a 3.0" center distance.

This explains the torque transfer capability increase in the 6-speed over all previous H-D 5-speeds. However, this is a complicated subject, and I feel that we should not take these ratings as gospel but use them comparatively. They are accurate in explaining that there is an increase or decrease; the exact amount is up for discussion. I talked to Bert Baker about torque ratings. "Torque ratings are voodoo. Torque ratings are established on a transmission dynamometer. A dynamometer schedule of a particular company is usually a guarded secret…A typical schedule might have 10 hours in first, 50 in second, 100 in third, 150 in fourth, and 350 in fifth for a five-speed transmission. In each gear, the dyno will put a percentage of total intended engine torque through the tranny. In first gear, 75% of the engine torque might be used because 100% traction in first gear is rare. In fifth gear, the tranny sees 100% all the time so the dyno schedule might use full torque for the 350 hours of run time. For BAKER Drivetrain, torque ratings are established relative to other products." [9]

Bert changes gears and explains further "The most influential factor related to bigger torque transfer capabilities is the center distance between the countershaft and the mainshaft, which in turn will dictate the diameter sizing of the gears. The H-D five-speed from 1980 to 2006 was a 2.5" center distance transmission. Center Distance is the biggest characteristic to consider for a relative idea of torque capacity. All transmissions in the aftermarket base off of the 2.5" design except the TorqueBox. The BAKER TB6 is a 3.0" center distance transmission. This is a very large transmission for motorcycles. The new H-D six-speed is a 2.8" transmission, which is considerably larger than the 2.5" one that it replaces. The left-side bearings on the new H-D tranny are larger than its predecessor, and that is good. However, the right-side bearings in the door are smaller and retained by beveled snap rings. We are greatly confused by this. The door is the Achilles heel of this new transmission as it relates to performance. Smaller bearings are not good for torque capacity and beveled snap rings will pop out under severe duty with helical gears." [10]

I agree totally, as I feel Bert is 100% accurate. However, putting things in perspective, I do not think this will be an issue for most riders as the transmission is stronger than the 5-speed, which served the Harley rider well for twenty-six years.

Now, would you use the new six-speed at the drag strip with a big beefed-up motor? Not me, man as the TB6 would be the hit. For those that love power, the Torque Box is a welcome addition to our world.

Of course, Bert has a fix for the Cruise Drive, which I will describe in a bit.

Improved Acceleration

The Cruise Drive transmission is all about improved roll-on acceleration, most noticeable off the line. However, I did not initially appreciate just how much better the Cruise Drive is at passing other vehicles. As I left my 5-speed riding partners in the dust while passing a tractor-trailer, their later comments wised me up to this fact.

Acceleration Comparison

Acceleration 60-80 mph	2006 FLT: 88c.i five-speed	2007 FLT: 96c.i six-speed
60-80 mph: 4th gear	7 seconds	5.5 seconds
60-80 mph: 5th gear	11 seconds	7 seconds

The figures are approximately accurate to within .5 seconds and listed for comparative purposes only. Real-time gains are impressive. White-knuckle-passing syndrome around tractor-trailers substantially reduces.

I will say…it is a pleasure to experience this acceleration increase after all the times I have been caught without enough juice to roar past an 18-wheeler or two and wound up white-lining between tractor-trailers traveling opposite ways. Doing it in heavy rain is real fun!

It's wonderful that the Factory for the first time I am aware of is matching powerbands to the needs of the rider. I talk ad infinitum about this in performance articles and am very happy to see the Factory addressing this simple but elusive concept.

Of course, the TC96 is going to be much faster with some performance modifications that will also match air-requirement delivery into the combustion chamber with the swept volume of the cylinders in order to burn more gas in line with the cubic- inch-size of the engine. In other words, when using higher flowing heads, with a slightly increased compression ratio, performance valve springs combined with higher lift and longer duration gear driven cams, and, of course, a self-tuning, emissions-free ignition we are going to have one happening motorcycle with much higher horsepower, even higher torque, and a perfectly matched transmission. I already know that my air/fuel delivery-modified TC96 will be very much faster than those dealer-upgraded 103s that, once again, neglect air delivery as they have since the advent of the Twin Cam in 1999.

Furthermore, the noise complaints need addressing; they are a nagging problem for a couple of reasons. Is the noise indicative of premature wear and impending doom? I do not buy into the doom scenario but time, one way or the other, will resolve the concern about premature wear. If there is no wear concern, there are still two problems:

Consumers are not happy with what they perceive as an annoying problem.

1. The transmission may not have met its EPA-directed objective of being quieter than the predecessor, the all-spur gear five-speed.

One longtime Harley owner that I cannot dismiss because I respect his mechanical abilities and Harley experiences complains that you must be going 2500 rpm for spur noise to go away in fifth gear. He says that there is a real rattle under that rpm both on his and a friend's Ultras. He feels that the noise is a result of being lulled by quiet helical gears that are full-contact all the time with no gear lash noise and then shift into fifth with spur-type gears that have gear lash where a loud clatter will result in lower rpm. He also does not have any reason to feel that the transmission may blow, as they all sound identical in his experience.

The Throwaway Harley

A future problem will evolve if the mainshaft or one of its four integral gears wears, it will necessitate replacement of them all since they are one piece. The same is true with the countershaft and its two integral gears.

Here we go again. It will become prohibitively expensive to repair the new transmissions. I think it is just one more step in assuring that Harley-Davidsons' will eventually become throwaways.

Since 1903, Harley-Davidson design encouraged rebuilding almost forever on a cost-effective basis. Flathead 45 cubic-inch models served well in World War II after being shipped overseas where in some cases they were exposed to corrosive salt air and water, used in desert warfare, burned, and blown up. Yet they still survive today. At Heavy Duty Cycles we still rebuild four or five a year for their avid owners, as well as a couple of old Flathead 80 cubic-inchers from the thirties. Just try to ride a modern Harley around the Sahara for a year or two and see what the sand does to them.

Planned obsolescence is a modern manufacturing principle defined as *a calculated period of time and/or usage that a component or complete vehicle will wear out.* How else can a consumer driven capitalistic society survive and regenerate? This started in earnest in some observers' opinion when H-D began experimenting in different alloys and manufacturing methods with the Evolution motor cases in 1987. The Factory replaced many thousands under warranty.

There is no disputing that the elimination of the guide blocks in 1991 that housed the tappets, with the introduction of the 5-speed rear belt Sportsters is an obsolescence factor. The engine case now houses the tappets. Once worn beyond factory specifications, the XL engine casings will need replacement instead of the predecessor inexpensive tappet guide blocks. This will make rebuild costs prohibitive relative to the bike's resale value, especially when compared to the cost of a brand new Sportster that is rubbermounted, has EFI, a rear fat tire, and fatter forks.

1. This continues with the elimination of guide blocks in the 1999 Twin Cam, which will become a similar scenario over time.
2. Later Evolution engine casings eliminated the steel insert that housed the pressed-in left-side power shaft end bearings. Press-fitting bearing races into relatively softer aluminum will not occur many times before the casing is worn out.
3. In late 2002-early 2003, the Twin Cam also abolished the pressed-in insert Timken races and tapered Timken sprocket shaft bearings in reliable use since 1956 in favor of the same roller bearing used in the pinion side to support the flywheels. Roller bearings do not fare well in side thrust, pulsating situations as experienced on the H-D power shaft.
4. In 2004, the Sportster eliminates the transmission trap door that allows the whole transmission to pull out of the engine casing for repairs from the right side behind the clutch. The reason given is that Sportster transmissions do not need repair. Geez, I did not know that since Heavy Duty Cycles makes a good living repairing XL transmissions. I do not know if a modern technician will be able to cope with rebuilding one of these without a lot of trial and error practice. The whole engine will need disassembly to split the casings to get access to the gears. Reassembly will happen many times in order to achieve correct endplay of the gears before the engine is put back together and installed into the chassis. However, us old Harley Dawgs will adapt quickly. We cut our teeth on the predecessor Sportsters before 1957 on the K Flathead models, some of which did not have trap doors either. I

rebuilt my first dozen transmissions this way before having the luxury of a trap door. However, Sportster rebuilds are beginning to become prohibitively expensive for the first time in their history.

Will the consumer pay close to the same cost for a rebuild as purchasing the complete engine or transmission assembly? Alternatively, will they buy a brand new bike?

1. There is the new cam support plate without conventional camshaft bearing supports; just two holes cut into the aluminum plate! Cost cutting through the use of CNC robotics is the other reason for manufacturing changes. Competition and bottom line shareholder profits requires cutting of costs. So here, is the double-edged sword. This is an ongoing trend for modern Harley-Davidson. This has everything to do with the Ying of planned obsolescence and the Yang of cutting manufacturing costs while maintaining quality.
2. Now we have the new six-speed transmission with:
3. A mainshaft is integral (one-piece), with 1st, 2nd, 3rd, and 4th gears.
4. The countershaft is integral with 5th gear and 6th gear.
5. This leaves six of the twelve gears in the 6-speed as individual gears and *serviceable* in H-D vernacular. I can guarantee the rebuilding costs are going to be horrendous when compared with twelve separate and serviceable gears with two detached stand-alone shafts, the counter, and mainshaft.

A manufacturer would not survive in today's world building old warhorses like the Flathead 45 that never become obsolete. After the marketplace saturated with everyone who wanted the product already owning one, then who would be left to purchase new products to keep the manufacturer growing? Harley's have to wear out or become obsolete after a period to ensure a rollover of buyers.

Many times new changes to a vehicle are an improvement. However, after some years, OEM (original manufacturer equipment) parts are no longer made to service out-of -date motorcycles. Without service parts, what will happen if not for a healthy aftermarket? However, if changes happen too quickly, there are not enough bikes of that genre for the aftermarket to profitably serve and protect.

All of this is inevitable for survival-of-the-fittest manufacturers.

Shift Clutches, Dog Rings, & Gear Dogs

S&S has a very interesting 1:1 direct drive six-speed.

1. All 6-sets for a total of 12-gears are helical for noise reduction.
2. Shifting mechanism lash reduces by using low-inertia shifting rings with 7-dogs compared with Harley-Davidson's 6-dog rings. This is different from noise-producing spur-gear lash

Before I fully explain what *dogs* are, let's go back to the 4-speed transmissions last used in the 1985 Softail. They used a shifter drum located on top of the all-spur transmission gears. The drum rotated by the rider's boot shifting the foot shift via the shifter linkage. The shifter drum had angular grooves cut into it where the tops of the two shift forks fit. The other ends known as *forks* of the shifter fork fit into grooves cut in the middle of the shifter clutches.

The two shift clutches; one for 1st and 2nd gears on the countershaft and the other for 3rd and 4th gears on the mainshaft have 6-wide splines on their inner diameter and mated to 6-splines on their respective shafts.

1. The 1st/2nd shift clutch has one-third-inch-wide splines.
2. The 3rd/4th shifter clutch has one-quarter-inch-wide splines.

The shifter clutches slide back and forth between their respective gears directed by the rotating shift drum during shifts. Each shifter clutch had small half-inch-wide lugs, or dogs, on their outside perimeter.

The 1st/2nd shift clutch has 5-dogs on either side.

1. The 1st/2nd gears have the dogs from the shift clutch slide into the spaces between the gear dogs on the sides of the gears to engage the particular gear.
2. The 3rd/4th shift clutch has 6-dogs on either side.
3. The 3rd/4th clutch dogs fit into mating indentations known as *indents* or *pockets* in the sides of the gears.

The shifter drum only allows one gear to engage at any one time. For example, if the shifter engages 3rd gear, up shifting from 2nd gear, the 1st/2nd shifter clutch will disengage from 2nd gear and slide along the shaft to the neutral position midway between the two gears. The 3rd/4th shifter clutch moves from the neutral position midway between those two gears and engages 3rd gear.

The reader may wonder why I am dwelling on the 4-speed transmission so much. It is because Harley-Davidson and some other aftermarket manufacturers are promoting a fresh advancement with their new offerings, which is the shift ring.

The H-D 5-speed transmissions incorporated the shift dogs and indents into the sides of various mating gears. The gears themselves, directed by the shift drum on top and three shift forks slide along their respective shafts, engage and disengage gears. The Factory heralded this as an efficient improvement, in the day.

H-D has gone back to a shifter clutch mechanism called *dog ring shifting* with the Cruise Drive, using the V-Rod style-design. The shift drum moves to the side from the top, using the Sportster XL/XB shifter design. There are 3-dog rings in the H-D 6-speed.

1. Two dog rings (1st/2nd and 5th/6th) with dogs on both sides.
2. One dog ring (3rd/4th) that is pocketed. The pocketed dog ring has no dogs or lugs but six indents on either side.

The advantage of these dog rings is that there is less inertia involved in moving them back and forth to engage with their respective gears. Compare this with the 5-speed having to move whole gears to engage other whole gears as. The 6-speed methodology sounds pretty close to the antiquated 4-speed system to me, albeit an improved and sophisticated version!

In order to make the dog rings even lighter with corresponding less resistance to movement also known as inertia, they ride on guide hubs. The three guide hubs, one specifically for each dog ring that are not interchangeable because of shaft/guide hub thickness and length, are multi-splined inside, and out. The inside splines rides on mating splines on their respective shaft, two on the countershaft and one on the mainshaft. The shift dog rings are also splined on their inside diameter to mate with the splines of the outside diameter of the guide hubs. The result is a lightweight shifting mechanism that is nimble and has the least inertial resistance possible, a huge improvement over the bulky 5-speeds, and a refined improvement over the dinosaur 4-speeds.

The overdriven ratio primary sprockets utilized by the Harley-Davidson Cruise Drive and BAKER's DD6 six-speed transmissions up their input into the transmission spinning the internal gears faster making it easier for the dog rings to engage when shifted.

1. Harley-Davidson switched to separate dog rings instead of shifter clutches integral with moving gears to actuate shifting.
2. Six-speed dog rings are much lighter than the moving gears of the 5-speed.
3. The result is less inertial drag (friction).
4. This change to a lighter mechanism results in lighter, easier shifts.
5. As great an improvement as the shift rings and guide hubs are, there is still much room for future redesign. As I related earlier, the S&S 6-speed has 7-engagement dogs relative to the H-D 6-dog system. S&S says that this lessens gearshift backlash, which results in easier low speed maneuverings especially in tight spots by minimizing lurching as the throttle is feathered. [11]

There is good reason for this increase in engagement dogs. As Bert Baker says regarding the H-D 6-speed, "The gaps between the dog clutch teeth and the corresponding openings in 5th and 6th gear are huge. When you lean into the throttle at low rpm, right in middle of the bikes torque range, the large mass of the mainshaft and the centrifugal force that it generates acts on the dog- teeth as they rattle around in the gear openings and then crash against the gears as you twist the throttle. This vibration is then sent through the mainshaft into the primary, aka "A Big Echo Chamber" and will cause the primary chain to 'snap' at throttle input. The stock configuration of 1st and 5th being spur gears only adds to noise and vibration that is transferred into the primary." [12]

The S&S 6-Speed

S&S provides a 34-tooth transmission pulley compared to the stock 32-tooth one. The transmission design is for 2006 and earlier engine sprockets (24-tooth or 25-tooth), combining with the 36-teeth or 37-teeth clutch sprockets. S&S claims, "When (the supplied 34-tooth transmission pulley) with a stock 70-tooth rear pulley, yields a final drive ratio that is equivalent to that of most overdrive 6-speeds." [13]

S&S goes onto making the same point Bert Baker makes that a disadvantage of overdrive transmission is that top gear meshes with a total four gears. In 1:1 direct, drive transmissions like the BAKER DD6 and the S&S, all-helical gear 6-speed, the input shaft (mainshaft) simply locks to the output (countershaft) gear and there are no meshed gears at all to create noise and frictional heat loss of transferred power.

Herein may lay another cause of noise with the H-D 6-speed since four gears are actuated in sixth, two fifth spur gears and two helical sixth gears.

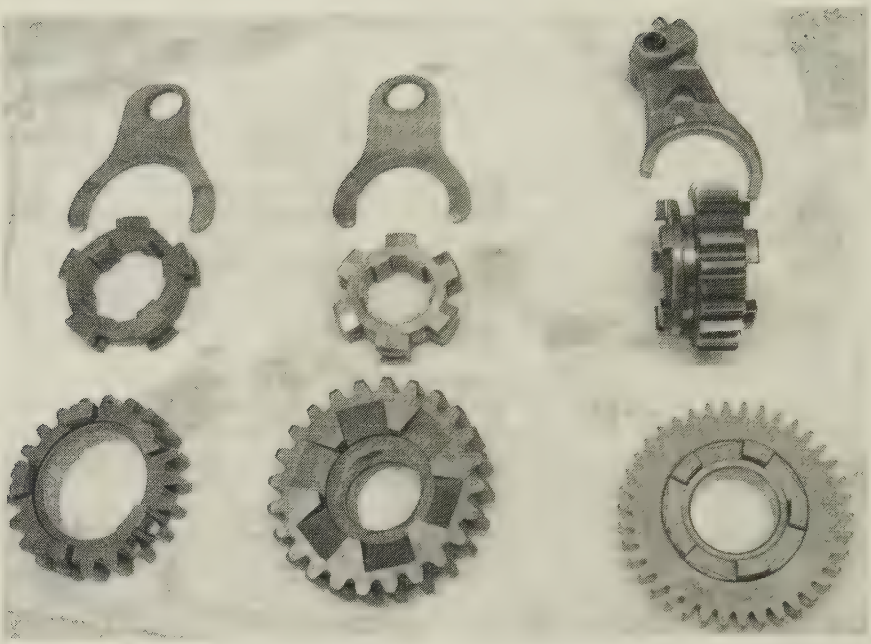
S&S talks about turndown ratios. I quote, "In simplest terms, turndown ratio represents the range of adjustment to engine speed (rpm) and final drive output by a particular transmission. It is calculated by dividing the lowest internal gear ratio by the highest, so turndown ratios in transmissions with a 1:1 top gear will always be the same as the ratio of the first gear. An overdrive transmission will have a turndown ratio that is higher than the ratio of first gear because the top gear ratio is less than 1:1." [14]

"This is important to consider because this "allows a touring rider to gear high for the highway and still have a first gear low enough to pull a loaded Bagger from a dead stop. Performance riders appreciate (this) because it allows them to launch hard at the drag strip… and still be able to ride in heavy traffic or at interstate speeds without difficulty." [15]

S&S also have calibration kits for electronic speedometers. Changing gear ratios and/or tire sizes require re-calibration of the speedometer if it is to read correctly. The S&S IST (intelligent spark technology), self-tuning carbureted-ignition-modules also have a speedometer calibration function for 2004-up models.

The noises complained about will not occur with the BAKER DD6 1:1 because fourth, fifth, and sixth gear-pairs are helical of which, some portion always engages to prevent backlash noise. As I have said before, the S&S 6-speed 1:1 has all six gear pairs helical cut, perhaps making it the quietest transmission on the market.

Unfortunately, both these transmissions will not fit into the 2006 Dyna or all the 2007 Big Twins. The design is to replace 2006 and earlier 5-speeds. However the BAKER DD7 bolts right into the new 6-speeds.



Comparing H-D 4-speed and 5-speed
Transmission Shift Dogs and Forks

The first vertical row is the 4-speed 1st/2nd shift fork, shift clutch (dogs), and 2nd-gear countershaft. The shift clutch *dogs* engage between protruding mating dogs on 2nd gear. Shown in the second vertical row are the 4-speed 3rd/4th shift fork, shift clutch (dogs), and 3rd gear mainshaft. The 3rd gear/4th gear shift clutch (dogs) engages between indented dogs or pockets in 3rd gear. 4-speed shift clutches are an effective but unsophisticated predecessor of the *dog rings* utilized on the H-D 6-speed. The last vertical row is one of the three 5-speed shift forks, with mainshaft 2nd/3rd gear. Notice the shift dogs on both sides of 2nd/3rd gear along with the shift fork channel. The 5-speed shift forks must move all this mass back and forth to engage mating gears. This inefficiency is eliminated in the H-D 6-speed with the light and agile dog rings that ride on a *guide hub* to engage gears.

The BAKER Solution

BAKER Drivetrain has a cure for the noise complaints many associate with the fifth gear in stock H-D Cruise Drive 6-speeds. The BAKER kit called the F6F, "features helical cut diamond ground gears, 28% wider bearings, a ⅛" thick bearing retainer plate, and a billet aluminum bearing door."[16] This combines to give the rider the advantage of a quieter 5th gear, eliminating 5th gear whine/clatter and the reduction of 5th gear drive train lash.

Remember that the H-D smaller end bearings with beveled snap rings may present problems with increased torque requirements. However, I must say now in 2010, I have not yet seen any problems in this area.

Defenders of the Cruise Drive emphasize that the emanating noises are simply different ones than those familiar to traditional riders. Consider that the transmission casing is stronger, gears are wider, most bearings are super-sized, dog rings are lighter, and shift points tightened. Furthermore, there are two extra gears. Four sets of gears are now helical with two interspersed sets of traditional spur gears. Of course, the emanating sounds will be different.

Some say the noises generated by the 6-speed is consistent with the above factors. I disagree as there is a noise problem beyond this. However, there is also truth to normal 6-speed gear-interaction noise being different from what Harley riders are used to.

Torque Transfer Loss

I discussed earlier with Bert Baker's comments regarding overdrive transmissions that also applies to this Cruise Drive situation. There will be a small loss in torque transfer because of a frictional (heat) loss of horsepower of driving 4-gears instead of two. Bert Baker adds, "Yes, (this is true) because being that the H-D transmission is direct drive in 6th gear, like our DD6 there does not 'need' to be 4-meshed gears. Just 6th main and 6th counter meshed." [17] He goes on to say, "The H-D design drives 3-gears and has a 4th along for the ride. It does not utilize the advantages that a 1:1 drive ratio can give you. Furthermore, Bert says, "In a traditional overdrive 6-speed the 4-meshed gears are needed to reduce the drive ratio below the 1:1 threshold to the .89:1, .86:1, or .80:1 ratio depending on the transmission. Not so with Direct Drive." [18]

In continuing with this torque transfer-loss theme, I asked Bert that since the Harley-Davidson countershaft is integral with countershaft 5th and 6th gears and 6th gear output power also needs four gears must result in a loss in torque transfer. "…You are correct that since 5th is pressed onto the C.S. that it is always spinning at the speed of the C.S. You are correct in thinking that there is torque loss to drive that 5th main gear even though it is riding on needle bearings and is not transmitting torque out the mainshaft". [19]

Then Bert added something I should have easily figured out, "There is also a measure of torque loss for the entire transmission while riding in 6th gear. This is due to the 1-piece structure of the mainshaft, with 1st-4th gears being part of the one-piece shaft. There is parasitic power loss to turn this very heavy shaft, which generates a great deal of centrifugal force. This bulky shaft design works to detract from the torque gains of utilizing a 1:1 6th gear configuration as well as making it shift like a tractor." [20]

The Rattle & the Fix

Now, from a noise perspective, I feel this is a cause of the additional 5th gear backlash rattle when in 6th gear especially at lower rpm's since the 5th spur gears must also turn. Of course, once put under load the noise will lessen or disappear to our ears. However, something was still nagging at my brain. The noise is more than this. I put the question to Bert; I am thinking this must be the reason for his development of the F6F fix? "The biggest motivating factor in the development of the F6F Kit was the noise of 5th gear…The fact (is) that it sounds like a broke down supercharger whining down the highway." [21]

Bert continues, "With all the helical gears having the teeth pointed in the same direction, all side thrust is transmitted in the same direction. This is most noticeable at low rpm, hard acceleration in 2nd gear, and the first helical gear in the transmission. There is noticeable clutch lever 'walking' at the handlebars as the torque band of the motor is delivering its payload down the mainshaft to the clutch. This excessive loading stress…will cause unhealthy and excessive wear and premature failure in the stock transmission, especially when stage kits and larger cubic inch motors are added to the equation. We purposely placed our diamond ground F6F 5th gear pair to have the helical teeth pointed in the opposite direction to help counteract the side thrust, this becomes more important since the 5th counter gear is pressed on the C.S. and is a participant at all rpm's and in all gears." [22]

In conclusion, I feel the much-improved Cruise Drive 6-speed transmission closely matches to the increased torque output of the TC96. I am happy with the performance of the transmission compared to what has gone before.

However, I do have some issues with, the already upgraded and superior dog rings that may need some improvement from 6-dogs to 7-dogs to lessen noise as they engage. This will also negate the further effect they (6-dogs) may have on sudden snapping (tightening) of the primary chain.

1. The 5th spur gear design may need rethinking both to counteract side thrust stress and to lessen noise. In fact H-D redesigns the 5th gear set in 2010.
2. Stronger bearings and their fitment in the trap door may also become an issue over time.
3. Lastly, the primary chamber will need some dampening measures to absorb noise rather amplifying it.

The bottom line is that I feel noise is an issue that needs addressing even though for some it may be perceptual. Well, it seems the Factory has introduced a 5th gear noise fix of …or is that an enhancement. Let's have a look.

The IDS Fix or is that an Enhancement?

Harley-Davidson is flying low under the radar with this one and with good reason…albeit, in my opinion, a selfish one. There is an innocuous addition to H-D's *2008 Genuine Motor Accessories and Genuine Motor Parts* catalogue. An unobtrusive entry on page 461 lists a rubber mounted rear pulley that only fits on 2007 touring model Twin Cams. The 2008-to-present touring models use this same pulley assembly as a stock addition.

Therefore, this kit is for one year only. I highly doubt any manufacturer would go to the trouble of making a kit that only fits some models of one-year production…or maybe it is just my suspicious mind at work again. I think Harley-Davidson is not calling this a fix to a problem of fifth gear noise in the Cruise Drive 6-speed transmission because it would be an admission that there is a problem._

The Isolated Drive System Sprocket Kit

This IDS sprocket kit (40287-07) is now available for retrofitting 2007 touring models, except HDI touring models sold in Japan, with a rubbermounted rear-wheel sprocket-pulley.

Wait a minute! How on earth, can a rubber mounted rear wheel pulley correct a transmission noise? Well, I am going to get to the answer for this very logical question as I progress. The reader may want to bone up on his/her high school physics for better appreciations of my explanation…ahh, don't bother, we will learn as we go.

The IDS kit will work on bikes with original equipment wheels and H-D accessory wheels except the 80-spoke laced wheel (42925-04), the polished aluminum solid spun disc wheel (43760-03), or the slotted 6-spoke wheel (43932-02 chrome, 43933-02 black).

The IDS rear drive-belt sprocket-pulley compensator bowl has six rubber joined dampers incorporated to form an isolated secondary drive system. The rear pulley has six stops cast in it on the inside portion facing the rear wheel compensator bowl. Thus, the rear wheel pulley, marries with the compensator bowl holder via the six stationary dampening rubbers that buttress against the pulley stops when assembled together. The pulley (40217-09) changes in 2009 with an increase to ten-joined rubber dampers (40278-09).

Sudden movement as in rapid acceleration in the rear drive train causes the pulley stops to compress the rubbers absorbing energy. *This design dampens power pulses emanating from the engine.*

Here we go again. Is this not about a transmission noise? Yes it is. The noise is coming from the 6-speed transmission fifth gears. How this noise occurs is the interesting part. I quote part of the blurb describing the IDS in the aforementioned 2008 H-D accessories catalogue, "…(The IDS) improves rider comfort and ride quality by dampening the mechanical noise and vibration caused by the engine's torque pulses…the motorcycle is quieter while accelerating, shifting and cruising." [25]

As for shifting, I can feel and hear the improvement the Harley *clunk* reduction with the IDS. The rubbers absorbing the sudden strain on the drive train softens the traditional Harley clunk when engaging a gear especially from neutral.

I think the key phrase from the H-D catalogue quote is *dampening the mechanical noise.* To me, the other feel-good marketing words bury this phrase in between. The intention, I am sure, is to cure the 5th gear clatter in the 2007 Twin Cams.

I don't think the Factory wants to admit liability for the fifth gear noise forcing a recall, voluntary or otherwise. Therefore, those annoyed by the clatter must pay for their own peace of mind.

In early testing, the Isolated Drive System successfully diminishes the 5th gear clatter!

One of my myriad of email buddies who is in tune with his 2007 motorcycle gave a glowing testimonial of the IDS from his experience. The first thing he noticed while running at 60 mph to 65 mph in fifth gear, the noise was all but gone. He was shocked, as he did not expect any effect on the 5th gear noise and had accepted the clatter because of the straight cut gears. He told me he had to listen intensely with the radio off to know the noise was still there after installation of the IDS. However, his biggest praise for the IDS was while running the backcountry roads and being able to settle into a particular gear and have no noise whatsoever. He then took the opportunity to lug her down to 1500 rpm in 4th gear and 5th gear and with smooth throttle, the bike just pulled right up without any clatter or chatter.

Another email friend, Mike relates, "I installed H-D's IDS kit on my '07 Streetglide. The bike always had the 5th/6th gear clatter since new in Sept. 06 and I have fought my dealer…ever since. At one point…H-D contacted me to bring my bike into the shop of my choice for them to test it. (They) said they had a few tricks they wanted to try. Other owners were also involved from various areas of the country. (The) Internet let me find a few of them. No one's bike was ever fixed to my knowledge in this testing. Most just sold or traded their bikes. I…was told…to watch for P&A catalogue release in July (2007) for a cure to this clatter noise. The IDS kit was it. This kit completely rid my bike of the clatter no matter the rpm or gear you may be in. I don't intentionally lug my bike but tried just to put this kit to the test. It works. (The) bike only has the sewing machine sound now….H-D has yet to say this kit was aimed at the clatter/tranny noise and have not offered these kits to known filers as a warranty item." [26]

Although these early reports are positive, we must wait for the mileage to pile up before declaring this as a total success. As of 2011, although there has been a redesign of the IDS in 2009, it seems that all is well.

Power Train Harmonic Pulse Dampener

Another reader hypothesized that perhaps the real reason for the Isolated Drive System is a power train harmonic pulse dampener that stops returning refraction back up the power train thus silencing the Cruise Drive 5th gear clatter. This guy, George is an astute observer.

I engaged in a lively email debate with George from Canada's East Coast. He thinks that those of us postulating that the 5th gear clatter originates in the Cruise Drive 6-speed transmission are missing the mark that the problem is one of harmonics, transferring noise reflecting back through the power train. George makes good sense and presents his case. "What the IDS does is dampen the reflection, i.e., stops it at the rear wheel....I believe this is due to the spur gear's capability of transmitting the full reflection without distortion. The helical cut gears dampen the reflection, reducing the chatter and as a side bar, eliminating the fifth gear whine completely. The problem is with the compensating gear in the primary...the IDS accentuates the compensator design capability...I think the compensator is not strong enough to do the job in 5th...it's unloading. I concur that the problem is really in the primary. That being said, because the compensator cannot absorb (dampen) the power pulse...it is delivered through the transmission to the rear wheel and is reflected back. I suppose it is like a whipping line tied to a post. The wave travels down the line, hits the post and reflects back. I believe this is due to the spur gear's capability of transmitting the full reflection without distortion. The helical cut gears dampen the reflection, reducing the chatter and as a side bar, eliminating the fifth gear whine completely. I think the theory is that a harmonic is being developed on the ignition stroke...and is peculiar to 5th...the IDS supposedly dampens the harmonic before it can be reflected back into the transmission." [27]

Clatter or Whine; Internet Theorists Expound on the Cause

The Internet discussions are labeling this noise as a whine. To me, it is not a whine but a clatter.

There are many theories as to the origin also; piston slap, spark knock, weak engine compensator, engine power pulses, primary echo chamber and of course, the fifth gear clatter. No matter the cause, since a piston slap is a slap, and ignition knock is a knock, a compensator knock sounds like all hell breaking loose, power pulses emanate as a vibration sensation, an echo is an echo and spur gear noise is a backlash situation that causes a single click or a multiple clatter.

Okay, definitions out of the way, here we go. I could tell both these guys as well as many others who emailed me are mechanically adept and had something to say that was worth listening to and examining. Any good mechanic can immediately identify the type of noise and its origin. Is the origin a backlash in fifth gear? *Maybe the clatter is the end-result and not the origin at all!*

1. To titillate the reader further, maybe it is not a normal backlash situation at all, as the spur gears engage under load.
2. Maybe it is a power pulse coming from the engine and transferring into the transmission causing the noise.
3. How could that be? The compensator sprocket assembly is supposed to absorb the energy of power pulses through its thick diaphragm spring plates.

4. Why would this situation not occur in 5-speed transmissions where there are five sets of spur gears? Thus, there are a few problems with the excellent email theories espoused.
5. I know that some respected people believe the noise originates in the front cylinder as a piston slap and travels back through the power train amplifying in the primary system.

Well, we at Heavy Duty Cycles have looked for evidence of piston slap and found none since it will leave telltale damage to both piston skirt and cylinder wall. Most good mechanics and I can hear and distinguish a piston slap from other engine noise. There is no piston slap that I have heard.

Detonation

However, an ignition knock is entirely plausible. Also known as pinging or detonation, spark knock is Harley-Davidson's old and ongoing nemesis. There are many false assumptions about detonation causes.

My email pal, Mike puts all the mythology like the popular colliding flame fronts to rest, as he explains detonation, "What actually happens is normal flame propagation generates a pressure wave as it travels across the combustion chamber. If pressure and temperature of the yet unburned mixture exceeds its ability to resist combustion the balance all goes off at once – detonates. There are many causes for detonation. The obvious two, poor quality fuel or over-advanced ignition timing are just the beginning. Anything that affects relative cylinder pressure is a part of the equation. Static compression ratio, valve timing, and the often-neglected rod to stroke ratio are very interesting variables to think about. When you increase the stroke with little or no increase in rod length, piston speed relative to degrees of crank rotation over TDC, go ballistic. Now consider that from the perspective of combustion chamber volume, pressures, fuel, and ignition requirements. Colliding flame fronts are an old wives tale." [28]

Mild ignition knock may not leave telltale evidence. In severe cases, there will be damage to the top of the piston crown and sometimes to the cylinder walls and the combustion chamber also.

Engine Compensators and End Bearings

Many people blame a weak compensator assembly for this noise. Proponents have spent much time on replacements and adjusting torque values of the compensator nut ever since the Factory replaced the very reliable tapered Timken bearing kits with a big roller bearing in 2003 on the rubbermount models and in 2000 on the Softails.

I initially dismissed these concerns after a check of the new compensator design and felt this issue a red herring. After all the compensator-sprocket dampening assemblies have been used on all Big Twins from 1965 and having first use in 1955 with great success in absorbing harmful engine pulses thus protecting the powertrain for over five decades.

Have I made a mistake?

Many mechanics, including those in the hi-performance crowd blame the oversized sprocket shaft roller bearing introduced in 2003 as the culprit. The sprocket-shaft-bearing supports the left side flywheel and its integral sprocket shaft in the left-hand-engine-casing on the power side of the motor.

I am no fan of use of this bearing for this purpose. However, it is the same bearing successfully used on the pinion side of the motor to support the right side flywheel and pinion shaft in the right hand engine casing. On the other hand, there is a big difference in stresses imposed in these two locations.

1. The pinion shaft and roller bearing primarily absorb up-down forces. Roller bearing design easily accommodates this stress function.
2. The sprocket side has this same supportive up-down force role, which again is not a problem. However, there are two types of pulses moving sideways along the sprocket shaft.
3. The first is the transfer of the power generated on the downward power stroke through the sprocket shaft, compensator, along the primary chain, through the clutch basket and transmission and finally back through the rear belt assembly to the rear wheel and the tire patch contacting the pavement.
4. The second is more difficult for the system to deal with. The 45-degree uneven and awkward firing order of the V-Twin delivers unwanted harmonics through the power train.
5. These vibrational forces wreak discomfort to the rider and mechanical parts alike. Thus, the uneven engine firing sequence is the main motivation for rubber mounting or counterbalancing depending on model to combat the negative effects of the ignition firing-pulses.

Hence, the primary reasons for the V-Rod, Metric V-Twins and the new breed aftermarket power plants like the S&S X-Wedge to increase the firing sequence to more comfortable vibration-lessening cylinder angles like 56-degrees or 60-degrees.

A roller bearing design function, no matter how big and strong is unable to withstand these side forces over time. I don't like this roller bearing, plain and simple, which replaced the very able, opposed and tapered Timken bearings and mating races used with great and enduring success from 1956 to 2002.

As much as I dislike the use of this roller bearing for this particular purpose, I cannot single it out and blame it for the 5th gear clatter. This bearing began use in 2003 in all rubbermount Twin Cams and in 2000 in all Softail models but the fifth gear, clatter did not occur until 2007. To further complicate the issue is that the 2006 Dyna Glide is outfitted with the Cruise Drive 6-speed and the sprocket shaft roller bearing but there are not any complaints I am aware of regarding clatter.

The noise begins in the engine possibly as a spark knock or maybe a simple power-pulse and travels through the power train back to the rear pulley.

A Band-Aid for a Symptom?

Kinetic energy pulses refract backwards from the rear wheel pulley through the power train, re-entering the transmission from the back causing the backlash clatter in fifth gear.

The mainshaft and countershaft 5th gears absorb the power pulses creating the noise via backlash clatter. There are spaces between the straight-cut gear teeth. Sixth, fourth, third and second gears are helical cut and are in constant contact with each other. Thus, backlash is not an issue in helical-cut gears. *If there were, no spur cut gears in the Cruise Drive this 5th-gear clatter would disappear.* Of course, the refracted energy pulses might manifest themselves in other ways or not at all…just roll back and forth like exhaust pulses. The spur cut 1st gear set does not make any discernable refractive backlash noise because the 5th gears have already absorbed the returning pulses.

The Echo Chamber

The noise emanates evenly in all directions from the transmission but the primary acts as an echo chamber resulting in the belief by some that the noises originate here. Switching from Syn 3 fluid to thick transmission hypoid gear oil will lessen but not eliminate the clatter.

Why is the 2006 Dyna Cruise Drive Unaffected?

Why is this not an issue with the 2006 Dyna Glide where the Cruise Drive 6-speed had first use? I think a number of factors easily explain this.

1. The Dyna is lighter, its riders more prone to higher rpm riding.
2. We already know that riding at higher rpm in fifth gear will lessen and/or cause gear clatter to cease. Dyna riders do not smell the roses as much as the big touring bike owners do.
3. Furthermore, the Dyna rear pulley is two-nubs bigger (68), than the 2007 Twin Cams (66), resulting in a higher secondary ratio of 2.13:1 for the 2006 Dyna versus 2.06:1 for the 2007 Twin Cams. This results in a final drive gear ratio of 2.88:1 versus 2.79:1 and an overall gear ratio of 2.96 versus 2.70.

Therefore, the *refraction whip* is pulsing with a different wave configuration.

1. Lastly, the Dyna and Softail primary system is a different shape and length from the touring models. The internal webbed support structure and dampening system is also of a dissimilar style. The echo chamber effect is muted.

I think the final answer of why the problem occurs primarily in 2007 touring models is a combination of factors that come together with each one alone incapable of causing the power pulse refraction noise.

1. The secondary, final and overall gear ratios are unique to 2007 and 2008 Twin Cams.
2. However, the 2008 touring models have the IDS system installed during manufacturing while the 2007 models have the traditional rigid mounted rear pulley sprocket.
3. The power-side sprocket shaft roller bearing has a part in transmitting power pulses.
4. Ordinarily the engine-compensating sprocket can cope with these power pulses in combination with the sprocket-shaft roller bearing. This depends on checking the crucial torque specification procedures of the compensator nut.
5. In contrast, the tapered Timken sprocket shaft bearings allowed up to and beyond 400 ft-lbs torque; 200 ft-lbs; or however much the backyard mechanic could muster with no ill consequences.

Is Super sized Gearing the Aggravating Culprit?

However, the kicker that brings this noise problem all together is the super sized primary gear ratios compared with the conservative ratios in predecessor Twin Cams.

1. This supercharged sprocket combination overwhelms the compensating sprockets capacity to absorb power pulses as effectively as before.
2. The pulses roll down the powertrain only to return back via the rigid mount energy-transferring rear pulley sprocket particularly at lower rpm levels. The returning harmonic pulses find the absorption point of least resistance, which, in this case are the spur cut fifth gears.

3. The pulse is returning back up the powertrain and is absorbed by the 5th gear spur cut gears before hitting the 1st gear spur cut gear set.

The IDS cure or is that a Band-Aid for a symptom is to rubber mount the rear pulley sprocket to absorb traveling pulses to prevent their transferring back…or, at least, disrupt the wave pattern of the pulses. Harley-Davidson, in order to preserve traditionalism of design, goes to inordinate lengths to mask symptoms as opposed to curing some problems.

We now have *compensator sprockets at the front and rear of the power train to curb the fifth gear clatter.*

A Possible Impending Trial on 5th Gear Noise

A frustrated 2007 Harley owner from Maryland, Russell Hall writes in a series of emails to me "In one of their correspondences to me, they (H-D) admitted that they corrected the issue in the 2008 models. However, they still refused to correct the problem in the 2007 models…A little more up-date on my case against H-D. I just received their answer to my complaint and they have requested a Jury Trial, I don't get it, they could have fixed the bike for what that cost them...Anyway my Attorney is Mark W. Howes, who is located in Annapolis, Maryland, phone # 410-266-1041. I share this with you in case you have received any other complaints or inquiries about the 5th gear whine from anyone who may live in Maryland and may be seeking some assistance. There must be more to this with H-D for them to go to this expense to defend an issue that is an easy repair for them by installing an IDS." [29]

Primary Compensator Fix

Furthermore, the engine compensator assembly that absorbs engine shock has been bottoming out. In 2008, there have been temporary fixes by adding an extra spring/shim.

The 2009 compensator (40296-06A) is now 7% stronger than the original part (40296-06). There is an undisclosed specification from the engineers at the Motor Company. The compensator spring assembly on 2008 to 2010 (one piece with the rotor) should measure no less than 0.670" from the top spring to the bottom of the groove. Anything less than this specification will make extra noise in the primary. Please see *Screamin' Eagle Compensator Fix: 2008* at the end of this chapter.

Fifth Gear Clatter Origin

Therefore, the spur cut gears *are not the origin of fifth gear clatter but the end-result of harmonic traveling pulses traveling unhindered back and forth* much like exhaust pulses do.

V-Rods spearheaded the IDS system and so far so good. However, the high rpm V-Rod torque curve is different from the grunt Twin Cam. The last time H-D attempted a rubbermounted compensator was around 1980 in the Shovelhead FXS Sturgis with disastrous results. Rubber technology has improved plus the IDS rubbers are larger and doubled in number.

I feel confident the IDS is a fix for dampening mechanical noise if experiencing the 5th gear clatter on a 2007 FLHT series Twin Cam.

In 2009, H-D redesigns the IDS. The rubber mount rear drive pulley compensator is now part of the rear wheel hub and separate from the rear drive belt pulley. The pulley is now just a pulley with no dampening function.

So, if experiencing the 5th gear clatter/whine on a 2007 FLHT touring model, then I feel confident the IDS is a fix...er, *enhancement* for dampening mechanical noise! Of course:

1. An all-helical gear 6-speed transmission like that provided by S&S Cycle, Inc. would eliminate a noise problem requiring a dampening solution. Unfortunately, this transmission has fitment as a 5-speed replacement.
2. The BAKER DD7, 7-speed transmission is a direct replacement for the Cruise Drive 6-speed will eliminate Cruise Drive 5th gear noise setbacks.
3. Ditto with the BAKER Drivetrain F6F helical gear fix for the Cruise Drive.
4. I also feel the stronger S.E. compensator assembly will help fix the problem even without an IDS rubber-mounted rear pulley.
5. In 2010, Harley-Davidson begins use of a helical 5th gear set replacing the 2006 to 2009 Cruise Drive 5th spur cut gears.

IDS Installation

Always use the Harley-Davidson workshop manual for any installation in conjunction with the Instructions sheet supplied with the parts. In this case, use the 2007 Touring Manual (99483-07), along with Instructions: Isolated Drive System, -J04467, Rev. 2007-06-28. This indicates the release date for the IDS is June 28, 2007.

1. As with any mechanical work, where injury may occur with accidental startup or battery powered rotation of parts it is crucial to disconnect the battery ground and the main maxi-fuse.
2. Also, remove any rings and hanging jewelry such as necklaces and wrist chains. Loose metal objects can short across powered electrical parts especially if acting as the ground. Rings can leave perfect scars around fingers if shorted out.

The IDS installation is straightforward.

Follow removal and installation of the rear wheel instructions in the manual.

1. The instruction sheet is informative and clear.
2. Two directives of note; the first is the bearing (40670-06), installation into the new final drive sprocket pulley (40265-08).
3. Use H-D tool, rear-wheel compensator sprocket bearing remover/installer (H-D-48921). Also, use this tool for removal of a worn bearing when servicing and replacing with a new bearing.
    a) The second ensures the new pulley sprocket threaded holes are deep enough for the new 7/16-14 hex screw bolts and captive washers (H-D 3814), holding the compensator bowl (40560-05), to the rear wheel.
4. A go-no-go gauge called a Gauge Screw, ($^7/_{16}$-14 x 1-1 ½) is supplied with the complete kit (40287-07). The nomenclature means the hole is $^7/_{16}$" in diameter with 14-threads per inch which is a standard sized national coarse (NC), thread. The bolt hole threads to a depth of 1 ½"-inches deep.
5. The stock wheel bolt-hole threading may not be deep enough as indicated by the go-no-go Gauge Screw. If not, thread them with a $^7/_{16}$-14 tap.
6. Wash away any old lock patch material from the sprocket pulley wheel mounting holes using a nylon brush with hot soapy water. Do not use a wire brush.
7. Now, install the six rubber isolators according to the instruction sheet into the compensator bowl (40278-08), after lubricating them with a half and half mix of water and isopropyl alcohol. Do not use oil or any other petroleum-based product for this purpose as it may cause the rubber to deteriorate.
8. Align the compensator bowl mounting holes with those in the rear wheel. The bowl obviously must face out for the pulley sprocket lugs to interact with the installed rubbers.

9. Install the bolts and captive locking washers in the standard crisscross pattern, alternately tightening back and forth until attaining a torque specification of 65 ft-lbs (88Nm).
10. Next, install the inner thick spacer (H-D 11846), against the inner compensator bowl bore.
11. Re-lubricate the rubbers where they will contact the sprocket pulley lugs with the water and isopropyl alcohol 50-50 mix.
12. Install the sprocket pulley ensuring the lugs seat fully.
13. When installing the wheel use the outer thinner spacer (H-D 11844) provided in the kit.
14. Tighten the axle nut to manual specified torque to seat the parts. Loosen and retighten ensuring the compensator bowl lip does not contact the inner sprocket face at any point in its circumference.
15. Reconnect the negative ground cable and the maxi-fuse and then put on any previously safety-removed jewelry.

The IDS (2008) will retail for about $375.00. Go for a test ride and the previous noisy 5th gear clatter will dampen as a result of the IDS absorbing engine generated power pulses. This Harley-Davidson riding pleasure *enhancement* should offer a successful Band-Aid to annoying noise for both rider and the EPA. I advise to also use the upgraded S.E. compensator to ensure a problem free ride.

Screamin' Eagle Compensator Fix: 2008

This beefy compensating assembly (40274-08) works so much better than the stock original TC96 compensating sprocket assembly (40296-06) and the improved one (40296-06A).

Obviously a new alternator rotor comes with the upgrade since it is integral with the compensator housing and springs.

The original 6-speed models have a four-spring pack compensator-rotor for both domestic and H-D International models.

- The S.E. upgrade incorporates two very large outside spring washers with one set about the diameter of unit, a medium size spring washer and one smaller one. The design appears to be progressive in order to complement larger motors down to the relatively smaller TC96 units. The compensator ramps are also changed. Start up bang should be a thing of the past.
- This new S.E. compensator is massive and in my opinion should been used in the first place on the TC96 models and especially the CVO 110. However, it becomes standard equipment beginning on the 2009 103c.i FLHTCUTG Tri Glide Trike. It also has fitment on the CVO S.E. models and the FXCWC Rocker C. The good news is that it will retrofit:

1. 2006 to present Dynas.
2. 2007-to-present Touring models.
3. Most Softail models excepting the FXCW, FXCWE and the FXSTSSE[3].
4. This S.E. compensator will be the best yet at controlling the engine pulses from a wide variety of build sizes. Some owners report their bikes feel stronger, with no startup bang.

Others that have installed the S.E. compensator on 2007 models without the IDS rear pulley dampener system report a slight tick sound. This would suggest that the new compensator is successful in controlling engine pulses traveling down the powertrain and reverberating back up into the transmission thus reducing fifth-gear click substantially. To take this a little further, a reinforced and stronger compensator may have been the cure all along making the IDS largely unnecessary. However, being a typical Harley rider where more is always better, it is nice to have both.

Importance overrides the risk of being repetitive; the compensator spring assembly on 2008 to 2010 should measure no less than 0.670" from the top spring to the bottom of the groove. Anything less than this specification will make extra noise in the primary.

In 2011, all touring FLT models come equipped with the CVO 110, Trike, and the FCWC Screamin' Eagle compensator sprocket. This should be the final solution but as always time will tell.

[1] Harley-Davidson Motor Co. 2007. *Harley-Davidson® Screamin' Eagle® Pro Racing Parts. 2007 Competition and Performance Parts for the Experienced Rider.* Page 67, Section G.

[2] Baker, Bert. BAKER Drivetrain. Part of interview with Bert Baker January 16, 2007.

[3] Ibid.

[4] Ibid.

[5] Ibid.

[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] S&S Cycle, Inc. *2007. '07 Performance Guide for 1999-'06 Big Twins with Twin Cam 88® and Twin Cam 88B™ Engines.* Page 74.

[12] Baker, Bert. BAKER Drivetrain. Part of interview with Bert Baker January 16, 2007.

[13] S&S Cycle, Inc. *2007. '07 Performance Guide for 1999-'06 Big Twins with*

Twin Cam 88® and Twin Cam 88B™ Engines. Page 75.

[14] Ibid. Page 75.

[15] Ibid. Page 75.

[16] BAKER Drivetrain. Website, http://www.bakerdrivetrain.com/f6f/index.htm, Industry Notice: The BAKER F6F Released in 5/07.

[17] Baker, Bert. BAKER Drivetrain. Part of interview with Bert Baker January 16, 2007.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Ibid.

[22] Ibid.

[23] BAKER Drivetrain. Website, http://www.bakerdrivetrain.com/f6f/index.htm, Industry Notice: The BAKER F6F Released in 5/07.

[24] Baker, Bert. BAKER Drivetrain. Part of interview with Bert Baker January 16, 2007.

[25] Harley-Davidson. *2008 Genuine Motor Accessories and Genuine Motor Parts* catalogue. Page 461, J. Isolated Drive System Sprocket Kit.

[26] Swaney, Mike. Email, Friday, August 17, 2007.

[27] GDJ (George). Email, September 12, 2007.

[28] Mike, my email buddy. Email. *Detonation and Octane* Nov. 29, 2004.

[29] Hall, Russell. Emails (3). Re: Donny Petersen (5th Gear Whine/Clatter). August 14, 2008 and August 15, 2008.

F6F BAKER Drivetrain 6-speed 2006 to 2009
Cruise Drive 5th Gear Clatter Solution

Pictured is the BAKER F6F kit that will fix 2006 to 2009 noisy 5th gear problems in the stock H-D 6-speed transmission. The F6F, "features helical cut diamond ground gears, 28% wider bearings, a ⅛" thick bearing retainer plate, and a billet aluminum bearing door." 23 All this combines to give the advantage of a quieter 5th gear, with no 5th gear whine and the reduction of drive train lash in 5th gear. The H-D smaller end bearings with beveled snap rings may present problems with increased torque requirements. Alleviating these concerns are the BAKER wider bearings, a stronger trap door, and the solid bearing retainer plate. As Bert relates, "With all the (H-D) helical gears having the teeth pointed in the same direction, all side thrust is transmitted in the same direction. We purposely placed our diamond ground F6F 5th gear pair to have the helical teeth pointed in the opposite direction to help counteract the side thrust." 24 With people in the aftermarket like Bert Baker, the symbiotic relationship with the Factory will only serve to drive continuous improvements to the Twin Cam. In 2010, Harley-Davidson replaces the 2006 to 2009 5th gear straight spur gear set with helical gears. In order to combat the extra side thrust generated by this change, the transmission mainshaft snap ring groove has been moved to the transmission inside approximately .090" for the purpose of providing additional support. The different placement of the snap ring groove obviously requires a new mainshaft. Furthermore, this spacing change also requires adding a counterbore to the existing guide hub that fits over the main shaft. The shifting dog ring rides on the guide hub. As I explain elsewhere, the guide hub is really a spacer that the shifter clutch dog ring moves back and forth on in order to engage its respective gears. The purpose is to eliminate clunky shifting that is so noticeable in 4-speed and 5-speed transmissions by making the shifter dog ring lighter and thus less cumbersome. Inertial forces reduce by less mass having to move back and forth. Is this 2010 Harley improvement able to retrofit back into 2006 to 2009 Cruise Drive transmissions? Part of the upgrade is and part is not. The H-D mainshaft in conjunction with other mating parts is retrofitable back to 2006. In fact, the mainshaft kit comprising of the new mainshaft, guide hub, snap ring and needle support bearing will be furnished for all replacement parts and 6-speed transmissions. However, the part we want, which is the helical 5th gear set is not currently retrofitable because the speedometer will read incorrectly at a higher speed than is actually being traveled. Also, the 6th gear light may or may not function properly. Currently, there is no recalibration available from Harley-Davidson although the aftermarket will be all over this one in short order. So, the helical 5th gear set is retrofitable if willing to put up with an incorrect speedometer reading and the indicator light possibly malfunctioning.

CHAPTER XI

Twin Cam Electrics

Harley-Davidson motorcycle electrics are a mystery for most riders. Measuring or monitoring the invisible electrons traveling through wiring and grounds is a daunting task. If the rider could see electricity in action, it would all become very simple. However, Harley riders all know that their motorcycle cannot function without electrical current. This all begins with the alternator charging the battery via the rectifier/regulator. I think every rider knows that the battery powers the ignition and the lighting system. None of this is that difficult if breaking down the various functions and not letting the whole deal overwhelm you.

Troubleshooting Shortcut: Check the Grounds

I will make two comments that every rider should memorize for when encountering anything electrical from annoying radio static to sitting on the side of the road with a motorcycle that will not run because of an electrical problem. By the time, the reader finishes this chapter; it will become abundantly clear that:

1. Improperly tightened or corroded grounds will cause more problems than any other single reason!
2. Every circuit must have a properly functioning ground to complete the electrical circuit.
3. Furthermore:
4. Grounds are always black, whether it is a thick battery ground cable or a thin rectifier/regulator ground wire.
5. The black ground wire or cable will always attach to solid mounted metal without rubber separation, usually the frame.
6. Electricity has difficulty traveling through insulating paint. Ground surfaces are always bare metal for best results.

Before I start discussing alternators and starting motors and stuff, it is necessary to protect the electrical system. If a wire shorts, there will be an electrical surge before stuff starts burning. In the old days, we used fuses, which would permanently blow to prevent the surge from burning the wiring system or circuit. Then H-D went to circuit breakers for many years which are reusable fuses. Today, H-D still sometimes uses a main circuit breaker but utilizes fuses for many other lesser but important applications.

The Evolution of Circuit Breakers and Fuses

My play on words is not accurate since my Harley-Davidson Parts Catalogue 1941 to 1984 (99456-84) says that first use of a circuit breaker (74586-70) is in 1970 on FL and FLH models, which were pretty much the only game in town back then except for Sportster's and the last Flathead 45's. I have a problem with this as my 1200cc 1966 FL Shovelhead ex-police bike had a 30amp (amperes) circuit breaker identical to the picture in the parts book.

Therefore, I think, the first circuit breaker came into use on either the 1966 Shovelhead or the 1965 Panhead since it was the first year of the 12-volt electric start. Perhaps this circuit breaker was only used on police bikes. This single circuit breaker was larger than anything used since then and was heavily insulated. It interrupted the power line off the positive side of the big electric start battery.

The parts catalogue quite correctly lists the first year of the smaller rectangular clip-in 15amp circuit breakers (74589-73) as 1973. Three of these circuit breakers found use on the FL/FLH, FX/FXE and XL models to monitor shorts on the ignition, lights, and accessories. In 1977, the introduction of a 30amp circuit breaker (74599-77) that looks the same as the 15amp ones functioned to protect the power supply from the battery. Lastly the first FX models in 1971 and 1972 utilized a 20amp circuit breaker (74591-71).

All Evolution models use circuit breakers to protect the electrical system circuits. Circuit breakers evolved from fuses. Fuses need replacement once overloaded by an electrical short. They blow, trip, or cycle off, take your pick of terminology, in order to cut off power if a short occurs to protect the electrical circuit otherwise the wiring will burn.

Shorts are usually caused by vibration with resultant wire insulation fraying, exposing the bare wire, which will short to ground if contacting metal.

1. Another common short is a loose connection vibrating to and touching a ground.

Circuit breakers are reusable fuses. They will trip when overloaded by a short and prevent power from traveling through their circuit.

Once the short cools down or is repaired, the circuit breaker will allow power to flow again.

If the short has not been repaired, the breaker will trip again and again until repaired.

- If a short appears to *go away* without repair, it is likely caused by a loose connection that shifts until touching a ground. It may shift again away from grounding thus giving the appearance that all is well…and it is until it shifts back again or causes other problems like dislodging completely thus preventing the electrical circuit from functioning at all.

Circuit breakers will trip or cycle off when amperage (amount of electrical current) in the electrical circuit exceeds the amperage rating of the circuit breaker. The thickness or *gauge* of the wiring largely determines the amount of amperage it can safely carry. The electrical circuit that the wiring serves will determine wire gauge. Each circuit breaker for the ignition, lights and accessories generally do not exceed 15amps while the heavier wiring of the main harness usually uses a 30amp to 50amp circuit breaker that interrupts the flow of electricity from the battery to the ignition switch. A tripped circuit breaker tells the rider that there is something seriously wrong within the electrical circuit it serves. Ignore this at your peril unless proceeding directly home or to your local mechanic.

Many circuit breakers have color-coded terminals for those in the know. If there is a copper colored and a silver colored terminal, they will indicate the power side as well as the circuit side.

1. The battery power wire always attaches to the copper colored stud terminal.
2. Regulator/rectifier wire will always attach to the silver colored stud terminal.
3. Accessory wire(s) will always attach to the silver colored stud terminal.

Always use lock washers, blue Loctite and tighten nuts to specification.

Shovelhead-Evolution Circuit Breaker-Fuse Amperage

	Main	Ignition	Lights	Accessory	Radio	Instrument	Constant
1966-1972 FL	30	NA	NA	NA	NA	NA	NA
1973-1978 FL	NA	15	15	15	NA	NA	NA
1978-1985 FL	30	15	15	15	NA	NA	NA
1971-1972 FX	20	NA	NA	NA	NA	NA	NA
1973-1976 FX	NA	15	15	15	NA	NA	NA
1977-1985 FX	30	15	15	15	NA	NA	NA
1984-1995 FXST	30	15	15	15	NA	NA	NA
1996-1999 FXST	30	15[1]	15[1]	15[1]	NA	15[1]	NA
1984-1994 FXR	30	15	15	15	NA	NA	NA
FXRT models	30	15	15	15	15	15	NA
1991-1995 Dyna	30	15	15	15	NA	NA	NA
1996-1998 Dyna	30	15[1]	15[1]	15[1]	NA	15[1]	NA
1984-1990 FLT	30	15	15	15	15	NA	15
1991-1995 FLT	30	15	15	15	15	NA	15
1996-1998 FLT	50	15[1]	15[1]	15[1]	15[1]	NA	NA
1999 FLT TC88	40[2]	15[1]	15[1]	15[1]	10[1]	15[1]	NA

Additional 1999 Twin Cam FLT Fuses

Brakes/Cruise	Radio Memory	EFI Fuel Pump	EFI ECM
15	15	15[3]	5[3]

EFI models beginning in 1995 with the FLTCU-I and the FLHTCU-I began use of two additional fuses. A 15amp blue colored fuse (72330-95) protected the fuel pump circuit while a 5amp light tan colored fuse (72331-95) protected the ECM.

These charts are approximate. Different manuals conflict on some uses. Consult specific manual for your model and year. Fuses begin to augment circuit breakers in 1989 and begin to replace circuit breakers in later years...except the main/battery circuit breaker whose amperage increases from 30amps to either 40amps or 50amps especially for fuel injected models.

[1] Fuses began to replace circuit breakers in midyear 1994. This is general information; please consult you manual for year and model specific information. The 10amp radio fuse also has use for police radios.

[2] Some manuals list a 50amp circuit breaker for EFI models.

[3] EFI model additional fuses: this is general information; please consult you manual for year and model specific information.

Fuses Make a Comeback: Usage Expands

Circuit breakers were the stalwart protection system against wiring shorts in the beginning circa 1970. As the wiring harnesses and electrical systems became ever more complicated, it became easier and prudent to begin a return to different amperage fuses for different applications.

Circuit breakers allow the rider to continue many times with minor problems or intermittent ones instead of dealing with the causal situation immediately. Fuses began use in conjunction with circuit breakers first with the FLT models because of their wiring complexity protection needs. Fuses work well protecting the Twin Cams because of the superb quality of their wiring and electrical systems.

In the beginning Evolution years, there were no protective fuses and usually four circuit breakers:

1. Ignition 15amp (74589-73).
2. Lights 15amp (74589-73).
3. Accessories 15amp (74589-73).
4. Battery 30amp (74599-77A) for the main system.

By 1989, the FLTC-U and FLHTC-U models incorporated:

1. Fuse, 1amp (72300-89).
2. Fuse, 3amp (72301-89).
3. Fuse, 5amp (72302-89).
4. Ignition 15amp (74589-73).
5. Lights 15amp (74589-73).
6. Accessories 15amp (74589-73).
7. Radio 15amp (74589-73).
8. Battery 30amp (74599-77A) for the main system.

By 1999, with the introduction of the FLT Twin Cam there is one circuit breaker and up to nine fuses:

1. Fuse; 2 x 10amp (72340-94, 72462-00).
2. Fuse; 7 x 15amp (72347-94).
3. Circuit breaker 40amp (74600-97A) or 30amp (74599-77B, 74599-97).

The 2006 FLT TC88 uses:

1. Maxi-fuse 40amp (72314-01).
2. Fuse; 9 x 15amp + 2 x 15amp spares (72330-95).
3. Fuse mini-amp; 3 x 10amp (72462-00).

The 2008 FLT CVO 110 EFI uses:

1. Maxi-fuse 40amp (72314-01).
2. Fuse mini-type; 3 x 30amp: ABS, Amplifier, spare (72539-06).
3. Fuse; 17 x 15amp includes spares (72330-95).
4. Fuse mini-amp; 2 x 5amp: heated grips + spare (72331-95).

The 2000-2005 Softail TC88B uses:

1. Circuit breaker 30amp (74599-77B).
2. Fuse; 4 x 15amp + 2 x 15amp spares (72330-95)

The 2009 FXST (except FXCW, FXCWC) TC96B EFI uses:

1. Maxi-fuse 40amp (72314-01).
2. Fuse; 11 x 15amp (72330-95).

The 1999 Dyna Glide TC88 uses:

1. Circuit breaker 30amp (74599-77B).
2. Circuit Breaker; 4 x 15amp (74587-94).

The 2000 Dyna Glide uses:

1. Circuit breaker 30amp (74599-77B).
2. Fuse; 6 x 15amp (72330-95).

The 2002-2003 Dyna Glide uses:

1. Circuit breaker 30amp (74599-77B).

2. Fuse; 7 x 15amp (72330-95).

The 2005 Dyna Glide uses:

1. Maxi-fuse 40amp (72314-01).
2. Fuse; 6 x 15amp + 2 x 15amp spares (72330-95).

The 2006 Dyna Glide TC88 EFI uses:

1. Maxi-fuse 40amp (72314-01).
2. Fuse; 10 x 15amp includes spares (72330-95).

The 2009 Dyna Glide TC96 EFI uses:

1. Maxi-fuse 40amp (72314-01).
2. Fuse; 10 x 15amp includes spares (72330-95).

The DYNA® MODELS 2009 HARLEY-DAVIDSON® PARTS BOOK (99439-09A) is confusing in that fuses are not listed in the contents; however, circuit breakers are. In the parts diagrams there are no circuit breakers but there are fuses listed. The 2009 Dyna Glide models use fuses not circuit breakers.

Sampling of FLT Twin Cam Fuses and Circuit Breakers

	1999 FLT	2005 FLT	2007 FLT	2009 FLT
Main	40amp [1]	40amp-orange	40amp-orange	40amp-orange
Ignition	15amp-blue	15amp-blue	15amp-blue	15amp-blue
Lighting	15amp-blue	15amp-blue	15amp-blue	15amp-blue
Accessory	10amp-red	15amp-blue	15amp-blue	15amp-blue
Instrument	15amp-blue	15amp-blue	15amp-blue	15amp-blue
Battery	-	15amp-blue	15amp-blue	15amp-blue
Brake/Cruise	15amp-blue	15amp-blue	15amp-blue	15amp-blue
P&A	15amp-blue	15amp-blue	15amp-blue	2amp max
Radio and/or siren	10amp-red	10amp-red	15amp-blue	15amp-blue
ECM power	5amp-tan	15amp-blue	15amp-blue	15amp-blue
Headlight	-	15amp-blue	15amp-blue	15amp-blue
ABS	-	-	-	30amp-green
Fuel pump	15amp-blue	15amp-blue	15amp-blue	15amp-blue
Radio memory	15amp-blue	15amp-blue	15amp-blue	15amp-blue
P&A ignition	-	-		15amp-blue
Exhaust control	-	-	15amp-blue [2]	15amp-blue
Starter relay	-	yes	yes	yes
Brake relay [3]	-	yes	yes	yes
Lighting relay [3]	-	-	-	yes
EFI System relay [3]	-	yes	-	yes
Spare	Yes-varies	15amp	15amp	15amp-blue
Spare	Yes-varies	10amp	10amp	30amp-green

Sampling of FXD/FXST Twin Cam Fuses and Circuit Breakers

	2000 FXST	2002 FXST	2005 FXST	2006 Dyna
Main	30amp [1]	30amp [1]	30amp [1]	40amp
Ignition	15amp	15amp	15amp	15amp
Lighting	15amp	15amp	15amp	15amp
Accessory	15amp	15amp	15amp	15amp
Instrument	15amp	15amp	15amp	15amp
Battery	-	-	15amp	15amp
Brake/Cruise	-	-	-	-
P&A	-	-	-	-
Radio and/or siren	-	-	-	-
security	-	15amp	-	-
ECM power	-	-	-	-
Headlight	-	-	15amp	-
ABS	-	-	-	-
Fuel pump	-	-	-	-
Radio memory	-	-	-	-
P&A ignition	-	-	-	-
Exhaust control	-	-	-	-
Starter relay	yes	-	yes	yes
Brake relay [2]	-	-	-	-
Lighting relay [2]	-	-	-	-
EFI System relay [2]	-	yes	yes	yes
Spare	yes	yes	yes	yes
Spare	yes	yes	yes	yes

Fuse blocks for EFI are obviously more extensive than for carbureted models. There may be two separate fuse blocks; a main fuse block and a smaller block for EFI. The EFI fuse block normally contains the EFI system relay; fuel pump fuse; ECM power fuse; an engine control fuse that is originally for HDI models only plus room for a spare fuse(s).

[1] This is a circuit breaker and not a fuse. Some manuals list this as a 30amp fuse.

[2] The four relay's (starter, brake, lighting, and EFI system) are not fuses but fit into the fuse panel. The EFI System Relay locates in the EFI fuse block. Only relays located in the main fuse panel or the EFI fuse block will be listed in the chart as a *yes.* EFI system relay does not locate in main fuse panel but in the subsidiary EFI fuse block.

The engine control fuse is originally for HDI (Harley-Davidson International) models only, which is why it is unfamiliar to most riders and many mechanics in the United States and Canada.

The Many Names for Conventional and Maintenance Free Batteries

Most Evolution motorcycles use *conventional* lead-antimony batteries. These are also called *spillable* or *Wet* batteries. There are many names for each type of battery currently used in a Harley-Davidson, which confuses people to no end. The cells in the Wet battery have lead inserts or plates. The added sulphuric acid electrolyte chemically reacts with the lead to form an electrical charge.

However, some 1998 and 1999 batteries (65989-97) particularly Softail and Dyna models as well as the majority of Twin Cams are equipped with *maintenance free* batteries also known as *Absorbed Glass Mat, AGM, valve-regulated lead acid or VRLA batteries.* These batteries come pre-charged and ready for bike installation. Most information is common to both conventional and maintenance free batteries except for maintaining electrolyte levels.

Maintenance free batteries are sealed and the electrolyte specific gravity cannot be checked or level added to. *Never* try to remove the sealing bar cap on the top of a maintenance free battery. Furthermore, the terminals may be reversed from the traditional location so the negative ground side is now on the right side of the motorcycle. In 2010, Harley-Davidson FLT models have gone to a dual post AGM battery meaning the battery cables can be installed on the front or side. Twin Cams for the most part use AGM maintenance free batteries.

The Many Names for H-D Batteries

Battery Type	Different Name References
Conventional	Wet
	Spillable
	Lead-antimony
	Flooded
Maintenance free	AGM (absorbed glass mat)
	VLRA (valve-regulated lead acid) [1]
	Lead-calcium
	Sealed lead-acid
	Acid-starved [2]
	Recombinant [1]

[1] VRLA valve-regulated lead acid does not wholly describe the technology. VRLA batteries are really recombinant batteries, which means that the oxygen (O) evolving at the positive plates, will largely *recombine* with the hydrogen (H) ready to evolve on the negative plates creating water (H2O). This prevents moisture loss. The valve is solely a safety feature in case the rate of hydrogen gas development attains dangerous levels.

[2] Maintenance free batteries use much less electrolyte than traditional lead-acid batteries hence the referral to acid-starved design.

Boosting (Jump Starting) a Dead Battery

Harley-Davidson manuals for the most part leave this topic out for servicing a depleted or dead battery. H-D lists procedures for checking, servicing, charging, and testing a low battery. However, riders boost low or dead batteries all the time. Harley obviously knows this because one of the ECM electronic control module's many functions is protection against errant jump-start battery boosting procedures by the owner or mechanic

Always remove the negative terminal first when removing a battery. Pay attention since early and late batteries have the negative terminals on opposite sides. Conversely, many early batteries have their terminals on the opposite sides of the later ones.

There are safety procedures to follow when working on either type of battery. Maintenance free batteries can still harm you or bike components because they still emit hydrogen gas and can crack under duress. Sulphuric acid on chrome or paint will ruin it. On your skin is unpleasant to say the least; in your eyes is devastating.

Never test a battery for charge by arcing across the terminals. If you are around Harley's long enough, you will see someone do this as a quick test. It is true that it is quick but not as quick as the potential for igniting hydrogen gas.

1. Wear protective safety glasses and a long sleeved shirt and pants whenever working on a battery. I'm old school, so I have never used face shields when working on a battery. I know better but was never taught to me and I developed a potentially dangerous bad habit. I guess, I am saying that it never occurs to me to wear face protection but it is a good idea. I always wear glasses when working on a bike because I wear them full time anyway.
2. Do not lean over the battery when making booster cable connections.
3. Boost a battery in a well ventilated area.
4. If boosting from a car, do not allow the car to touch the bike that is being jump started. Turn the car off for H-D battery boosting.
5. Ensure the boosting battery is 12V (12-volt) and fully charged.
6. Attach booster or jumper cables in the following order:
    a) Positive to positive.
    b) Avoid touching a positive to a ground. A spark can easily ignite hydrogen gas emitting from the sulphuric acid electrolyte.
    c) Attach the negative cable to the booster battery's negative terminal next.
    d) Attach the other end to a ground *away from the battery* like an unpainted engine bolt. Attaching the negative jumper cable to the negative battery terminal of the bike about to be boosted may spark causing a hydrogen gas explosion. Painted parts may have to be scraped to provide a sufficient ground. Crash guards make a good ground but there is a slight chance the chrome may discolor.
    e) Do not let children or pets play around open batteries, electrolyte, or charging equipment.

Check the electrolyte (fluid) in a conventional Wet acid-lead battery before attempting to jump start your bike. Electrolyte is a diluted sulphuric acid solution. Do not attempt to add fluid to most Twin Cam batteries, which are maintenance free. The battery can rupture or explode if:

1. There is no visible electrolyte in the cells.
2. The electrolyte is frozen.

All of the above may sound dangerous and it can be. Follow the safety guidelines and it is a safe procedure to perform. In 35-years, I have had two batteries explode on me on the thousands of times I have worked with them. And guess what? Both times were preventable as it was my fault for neglecting safety procedures. The explosion will scare the bejeesus out of you. Luckily, I did not get hit by a projectile nor did I get acid sprayed on me but that is just pure luck. However, luck is not required when doing mechanical procedures correctly.

Starter Motor Damage

During the boost, do not operate the starter motor for more than 6-seconds at a time. It can easily overheat creating another problem. Allow at least 15-seconds between boost attempts.

Electrical System Damage

I think almost everyone violates this one. Once the bike starts, run it at a low to moderate rpm. Do not rev the bike until it is warm. There is no need to cause engine damage.

1. Also, blipping the throttle when an Evolution or Twin Cam engine is cold can blow a head gasket.
2. High rpm running with battery booster cables attached can cause electrical damage.

Remove the jump start cables in exactly the reverse order they were attached.

Battery Care

Both conventional and maintenance free batteries still use cells that have lead inserts or plates. The sulphuric acid electrolyte chemically reacts with the lead to form an electrical charge.

A battery will generally stay in good condition if current input from the charging system balances with the battery draw. Therefore, too much unbalanced input current as well as too much output can damage a battery. Furthermore:

1. Cold weather will weaken a battery's capacity to store electricity.
2. Vibration is the enemy of the battery. This is one reason that batteries last much longer on rubber mounted FXR's, Late Dynas and FLT's than they will on pre-counterbalanced rigid mount Softail models.

Maintenance Free Battery (VRLA or AGM)

VRLA batteries always include a safety pressure relief valve as opposed to a vent used by a conventional Wet battery. A VRLA battery cannot spill its electrolyte (battery acid) if it is turned sideways or upside down. They also use much less electrolyte than traditional lead-acid batteries hence the referral to acid-starved design.

However, valve regulated does not wholly describe the technology as VRLA batteries are really recombinant batteries. Recombinant means that the oxygen (O) evolved at the positive plates will largely recombine with the hydrogen (H) ready to evolve on the negative plates to create water (H_2O) thus preventing moisture loss. The valve is solely a safety feature in case the rate of hydrogen gas development attains dangerous levels.

Normal Battery Discharge Rates

When charging a battery, take note if all cells show signs of hydrogen gas bubbling.

- If a cell has no gas bubbling, it is probably shorted and the battery may need replacement.
- If the specific gravity of a cell is too low, it may be shorted and the battery might need replacement. Specific gravity cannot be checked on the late maintenance free batteries.

If a battery is not used for a week after having an initial full charge, it is defective if:

- Losing its charge within the week.
- The specific gravity, which can only be checked on a conventional battery, drops quickly.

A fully charged battery should only self-discharge about 1% per day of inactivity.

Wet (Conventional) Battery Replacement

When replacing a dead or weak acid-lead conventional battery with a new one always remove the negative cable first before the positive cable to avoid sparking. Installing a new battery is done by attaching the positive cable first and negative cable last.

1. Do not activate a new Wet battery in the bike as electrolyte (sulphuric acid) spillage is wonderful paint remover and just loves to damage chrome.
2. On most batteries the vent nipple will be sealed with a tube. *Always remove this sealed tube* before filling with electrolyte and especially before charging and installation in the bike. Charging will create hydrogen gas. Gas expands. If the vent is blocked, there is potential for a pressure explosion or battery case breakage.

The proper procedure with a new conventional acid-lead battery, which all Evolution models use up until 1997-1998 that requires added electrolyte is to:

1. Remove the battery vent nipple sealed tube.
2. Inspect the vent nipple for any obstruction and cleanliness.
3. Install the long vent tube to the nipple.
4. Place the end of this vent tube into a suitable receptacle like a marked bottle. I almost said a coke bottle because that is what we all used forever in the old days. As I began writing this, I realized how stupid this was and the potential horrific damage if someone like a child took a drink of electrolyte overfills.
5. Remove the six battery cell filler caps.
6. For *first filling,* use only electrolyte. Do not fill with tap water, distilled water or any substance other than electrolyte.
7. If requiring top up fluid after the battery has been activated use only *distilled water*, which is chemical compound free.
8. Do not use electrolyte for top up. The solution may become too strong if refilling with electrolyte. This can cause a weakened battery.
9. Specific gravity of electrolyte should be 1.265 at room temperature, which is approximately 70° F (21° C). The acceptable range is 1.260 to 1.280. Different manuals will give slightly different acceptable specific gravity figures but they will be at a different temperature, which usually corrects to what I have listed here.
10. This also applies to maintenance free batteries. The first installer, whether it be the manufacturer, bike shop, or the home mechanic-rider adds electrolyte to the battery when activating it for the first time. After testing, the sealing bar cap is placed over the top of the battery cells. It should never be removed. Therefore, specific gravity checks are not possible after initial activation. Proceed to a load test if necessary for an accurate determination of maintenance free battery condition.

Specific Gravity

Everybody throws this term around when talking about electrolyte and battery charge but what does it mean? I learn a great deal while writing, always conscious of not making a mistake or passing on bad information. Specific gravity of a liquid is measured by use of a tool called a hydrometer (hydro = water, meter = measure), which is basically a large and crude syringe. The H-D part number is HD-96910-35, which indicates use as a Harley tool from 1935 to a least near the end of the Evolution era in 1997. Initial electrolyte filling of a Twin Cam maintenance free battery also allows hydrometer testing.

Hydrometers are inexpensive and readily available at any automotive parts store. It has a glass center tube with a rubber bulb at one end and a rubber nipple at the other. Fluid is drawn up into the glass tube where a free-floating measuring stick resides. The stick will rise further in a fluid with a specific gravity greater than water and will sink lower in a fluid with a specific gravity less than water. The stick for lack of a better word may be color calibrated or the glass tube itself may have more accurate calibration line markings for reading the exact specific gravity of the battery electrolyte. The measuring float-stick or calibration measures the difference between water density and that of the measured fluid. The stick will float higher in electrolyte than water because it is denser than water.

Hydrometers are used for all kinds of interesting stuff like winemaking and maple syrup production. The density of fermenting wine relative to water (specific gravity) will indicate how far along the fermentation process is. The weight of maple syrup relative to water (specific gravity) will let the harvester know when it is time to gather the syrup.

Measure from the Bottom of the Meniscus

When measuring the depth to which the hydrometer stick sinks, the user must be aware of the Meniscus formed between the hydrometer extension and the electrolyte surface. Imagine a straw placed into water as an example. Look closely at where the straw inserts into the water. The water level will be higher around the contact area with the straw. This angling up of the water or any fluid for that matter is called a Meniscus. So where do we take a measurement from? The accepted practice is to measure from the bottom of the Meniscus in line with the liquid surface.

Techno-babble for the Geeks

A mechanic does not have to know exactly what specific gravity is. However, he or she must know what specific gravity levels are good and what are not. For the techno-geeks, it is the ratio of two quantities that have the same dimensions measured as mass per unit volume. The standard of comparison for liquids is water at 39.2^0 F (4^0 C), which has a density (weight) of 62.4 pounds per cubic foot (1.0 kilogram per liter). I will take an extreme example of the heavy metal liquid mercury. Mercury has a density of 848 pounds per cubic foot (13.6 kg/liter). Therefore the specific gravity of mercury is 13.6.

Electrolyte has a specific gravity or density (weight) greater than water. We know, which weights or specific gravity range are suitable for a charged battery and which ones indicate a discharged battery. For example an electrolyte specific gravity of 1.270 means that its density or weight is 1.270 kilograms per liter. A kilogram is 2.2lbs and a liter is a little smaller than a quart. Four quarts equals one U.S. gallon. Approximately 4.5 liters will equal one gallon.

Temperature Correcting Specific Gravity

If the battery electrolyte temperature is not 70° F (21° C) there is a simple calculation to correct the hydrometer reading. Other reference books use 80° F (25° C) as the initial corrective temperature start. Whatever starting calculating figure used; it will all work out pretty close in the end.

1. For each 10° F (5.5° C) below 70° F (21° C) subtract .004 from the hydrometer specific gravity reading.
2. Conversely, for each 10° F (5.5° C) above 70° F (21° C) add .004 to the hydrometer specific gravity reading.

For example, if the hydrometer specific gravity reading is 1.270 at 80° F (27° C); subtract .004 from 1.270 to obtain a corrected reading of 1.266 for 70° F (21° C). The reader does not need to be this precise down to .001; just be aware to be within the bounds of about 1.260 and 1.275.

Some hydrometers are temperature compensating, which will eliminate the necessity of mathematical temperature correcting computations.

Specific Gravity versus Battery Electrolyte Charge

Specific Gravity	Battery Charge (%age)
1.275	100%
1.245	90%
1.225	80%
1.205	70%
1.185	60%
1.170	50%
1.155	40%
1.140	30%
1.120	20%
1.080	0%

Figures are approximate. On maintenance free batteries specific gravity testing is not possible except after initial filling. Proceed directly to a load test.

Battery Acid Specific Battery

Up until around 1989, it is recommended to use a *hot* battery acid with a specific gravity of 1.280. By 1989, battery technology and quality improved so that a *cooler* battery acid with a lower specific gravity of 1.265 will suffice.

Hydrometer Use

Always recharge a battery after adding distilled water to starving cells on conventional acid-lead batteries before testing with a hydrometer for specific gravity. This may take as little as twenty minutes. Allow the production of vigorous bubbling that produces hydrogen gas that will mix the electrolyte and distilled water thoroughly. Even though the individual battery cell caps are vented as is the complete battery via the vent tube, I always unscrew the caps and leave them loose above their cells in case there is a vent blockage. This is an added safety feature that many think unnecessary because we always check the battery cap vents to guarantee there are no blockages…right?...yeah, sure!

Remove the battery caps for hydrometer testing since access is required for the hydrometer nipple to draw up electrolyte into the center glass tube. Hold the hydrometer vertically at a 90° degree angle to the battery top. The bulb on top is squeezed tight before inserting the nipple into the electrolyte. Once inserted, gradually release the bulb creating a vacuum, which draws up the fluid.

When utilizing a temperature compensating hydrometer, gradually draw up electrolyte into the glass tube until the internal float floats freely and then release the electrolyte back into the battery by squeezing the bulb. Do this a few times to ensure the thermometer has adjusted to the electrolyte temperature before taking the reading.

This is not necessary with a non-temperature compensated hydrometer so the first reading is fine for proper testing. In either case, once ready, note the calibrated number or color-code in line with the surface of the electrolyte. If required, make the temperature compensating calculations for the actual specific gravity.

Battery Recharging

Recharge a Wet conventional battery if the electrolyte specific gravity slips below 1.220. Other signs that a recharge may be necessary are:

1. Bike storage such as for the winter or for whatever other reasons.
2. A slow laborious electric starter.
3. Bike lighting is faded or fading.

Battery Charging Time

Do not use a powerful automotive battery charger, which will weaken the smaller motorcycle battery's integrity. *The best way to charge a battery is slowly.* Therefore, a trickle charger with a 1amp or less charging rate is ideal. Many times, trickle chargers are available from local automotive supply stores. One company that specializes in them is CHRISTIE Distribution & Service Center Div., Lake Forest, CA, (www.christiecbs.com). The problem with trickle chargers is that it takes up to 30-hours or more to charge a battery. However, it is worthwhile to do it this way since battery life increases, which means pocketbook savings and reduced inconvenience.

Alternatively, the use of a 2amp to 8amp variable-tapered rate charger will provide almost as good battery life and will charge the battery faster. This process can take at least 10-hours. This sounds contradictory to low-amp charging but after an hour or two, the charging rate lowers to 1amp or less for the remainder of the charging time.

Battery Charging Rate: Divide Amp-hour Rating by 10

A slow charge, which is the only way for battery care is *one-tenth of its given capacity*. Therefore, a Softail with a 19amp-hour battery should not be charged by more than 1.9amps. A Twin Cam FLT with a 28amp-hour battery should not be charged by more than 2.8amps.

1. Remove the battery from the bike for recharging unless utilizing a battery tender (see below). Disconnect the negative cable first.
2. Remove the 6-filler caps on a conventional battery and ensure:

   a) The vent line is not blocked or kinked.
   b) The battery cap (6) vents are working properly.

3. If the electrolyte is below the top line on the battery casing, refill the battery with distilled water to the top line. Ignore this step for an AGM/maintenance free battery. In this case replace the AGM battery if a cell has a low fluid level.
4. Always charge a battery in a well ventilated area to allow hydrogen gas to dissipate harmlessly.
5. Do not turn the battery charger on until the cables are attached. Attach the positive charging cable first to the positive side of the battery, which will be marked with a +. Attach the negative cable to the negative terminal, which will be marked by a minus sign (-) afterwards.
6. Do not smoke around batteries; or weld or do anything else that might ignite hydrogen gas.
7. Lower the charging rate if the charger generates excessive hydrogen gas. If this is not possible, a different lower amperage battery charger is required.
8. Excessive temperatures may distort internal battery plates or cause an internal short circuit. Lower the charging rate if the battery heats up to 110° F (43° C). This may necessitate a lower amperage battery charger. Also let the battery cool down.
9. Always disconnect or turn off the battery charger before removing the charging cables from the battery terminals. An inadvertent spark can ignite the explosive hydrogen gas.
10. Disconnect the negative cable before the positive cable. The reason for this is that current cannot flow and therefore potentially spark if there is no ground to complete the electrical circuit.
11. Charge the battery until 100% (specific gravity of 1.260 to 1.275).
12. Then, as a follow-up, dislodge air bubbles from the internal battery plates by carefully shifting and tapping the battery.
13. If the electrolyte has lowered on a Wet battery below the top fill line, refill with distilled water.
14. Do not use sulphuric acid (electrolyte) for refills or topping up an activated battery's electrolyte. This may make the electrolyte too strong thus weakening the battery and its potential lifespan.
    a) Do not overfill as charging will likely force excess electrolyte out the vent tube. This will not only cause damage to parts it comes in contact with but the electrolyte depletion may weaken the battery and its potential lifespan.
15. Retest the specific gravity on a Wet battery.
16. On a Wet battery if it has lowered below 1.260, recharge until the battery tests for a full charge specific gravity. This will generally take an additional one to two hours.
17. On a Wet battery allow the battery to sit after charging and gestate for at least one hour before testing specific gravity for a full charge.
18. On a Wet battery compare the specific gravity of each cell to the other five. The highest and lowest temperature corrected specific gravities should not vary by more than .05-specific gravity. I have seen literature that says this difference should not vary by more than .01-specific gravity. This differential will cause a high discard rate of batteries that will otherwise function properly. As always, not everyone has deep pockets and can afford this strict regimen.
19. Furthermore, on a Wet battery no one cell can have a specific gravity of less than 1.220 after charging.
20. Electrolyte or dirt on top of the battery can cause battery discharge. Cleanliness with all things mechanical is next to godliness.

21. To save paint, chromium, and your skin:
    a) Install the 6-battery filler caps on a Wet battery.
    b) Gently wash away any acid (electrolyte) spillage with tap water.
    c) Sodium bicarbonate (baking soda) will neutralize electrolyte. Be careful with its use since it will lessen battery life if it enters any of the cells. The correct solution for this neutralizing purpose is about 5-teaspoons of baking soda per quart or liter of water. This is not precise and does not need to be since I realize a quart and a liter, while close are not equal in volume.
22. Install battery in the bike:
    a) Ensure battery posts, wire/cable connectors and the frame ground is free of corrosion, oxidation, and paint. If necessary clean with a wire brush or sandpaper.
    b) Make certain that the battery cushion(s) are installed first. These often get misplaced. Remember, vibration is a prime enemy of battery longevity.
    c) Attach the positive side first followed by the negative cable. Specification for tightening hold down bolts is around 40 in-lbs (4.5 Nm). The terminals are lead and are relatively soft. In other words they break easily. I make no money saying this since I sell a dozen batteries a year because of over tightening causing broken terminals.
    d) Sometimes small spacers are supplied to fit between the cable end and the battery terminal with a longer bolt for stress free attachment. I see batteries in bikes at my shop all the time where these have been lost or discarded. Stressed parts will break rapidly especially when vibration enters the equation.
    e) Coat attached terminals in petroleum jelly (Vaseline) to prevent and protect against oxidation or corrosion. I used whatever grease was handy for most of my career.
    f) Route cables so they are not stressed or rubbing against other moving or hot parts.
    g) Ensure the vent hose on a Wet battery is attached to its vent nipple with a squeeze-clamp, free of obstructions, and routed away from hot (exhaust, right side) or rubbing parts (belt drive or chain, left side). Beginning around 1990 some Yuasa supplied H-D batteries particularly for Softail models have a *barbed* vent so that a squeeze-clamp is unnecessary. The end of the vent starts at the customary diameter but mushrooms before returning to the regular diameter. Thus the tube forces over the mushroom and back to the standard diameter pipe, which effectively holds it in place. Remember that highly flammable and explosive hydrogen gas may be exiting. The routing may be complex to avoid danger. Therefore, ensure there is no kinking, which will obstruct exiting gases. The vent tube should hang below the lower frame member so any hydrogen gas exits into the atmosphere. H-D manuals lay out safe routing for the vent tube on different models and years. H-D routings are complex but obviously thought out and safe.
    h) There is another venting safety feature that very few riders or mechanics are aware of. It is possible for the bottom of the Wet battery vent tube to clog with road debris or melt shut if it comes in contact with heat from the exhaust pipe. The corresponding buildup of gaseous pressure within the battery may crack the casing with resultant damage and in extreme cases, explode. To prevent this, the vent tube has a slit near one end that will open with building pressure from within. Ensure the slit-end of the vent tube attaches to the battery vent nipple. I'll betcha, you didn't know that one because guess what, neither did I.

Rectifier Damage

The rectifier is part of the charging system.

It converts alternating current (AC) produced by the alternator and changes this to direct current (DC) for battery charging.

1. Secondly, the rectifier ensures charging is at a safe rate, restricting electrical flow to the battery to prevent overcharging with subsequent electrolyte depletion, excessive hydrogen gas production, and battery damage.

Connecting battery cables backwards can damage the rectifier. Dangerous sparking will also occur, which is the first clue to the installer's negligence.

Sulphation

All batteries have a set life cycle depending on operating conditions, proper maintenance procedures, and a balanced discharge-recharge electrical system before needing replacement. Battery life is easily extended if adhering to some basic principles.

Start with a good quality battery. Sound overly simplistic? Well, there is a national automotive store that sells batteries for less than most others. For automotive purposes, the batteries seem okay. However, their inexpensive motorcycle batteries are not designed for bike needs and H-D vibration. They constantly lose specific gravity until the bike cannot function.

1. Attempt to reduce vibration since this is the big battery killer.
2. Use proper size battery cables with soldered ends. One trick for helping a Harley that has cranking problems is to install thicker cables. Some year Evolution bikes have too small gauge cables. Starting improves greatly by replacing these with thicker gauge cables.
3. Ensure the cable and battery post clamps are tight and corrosion-free.
4. Keep the electrolyte continuously at a specific gravity of 1.270 or higher on a Wet battery.
5. Top up a Wet battery with distilled water on a regular basis. Summertime requires more frequent maintenance since hydrogen gas forms more freely thus depleting electrolyte.
6. Ensure the alternator charging rate is high enough to service all motorcycle accessories. Early Evolution Baggers, FXRT's, and Heritage Softails to a lesser extent and some early Twin Cams can use alternator amperage upgrades. H-D played catch-up in these years in providing enough juice to service their models that increased battery draw through expanded electrical accessories.
7. Avoid battery plate sulphation. Sulpahtion is the other great battery killer. Vibration increases sulphating but there are other causes that I will describe.

If a battery operates under a heavy electrical load known as deep cycling, the electrical draw may exceed the charging rate of the system. Discharge and recharge must balance. This is another reason Evolution and Twin Cam batteries lasted longer as the years progressed, simply because the upgraded alternators began to match the electrical needs of the motorcycle. Most Twin Cam models now have excellent matched batteries with their charging systems. I recommend upgrading alternator Shovelheads and early Evolutions, specifically those with lots of accessories to the 38-amp H-D alternator. This will require a stator, in some cases the rotor, the rectifier and perhaps a battery amp-hour upgrade to complete the system.

Deep-cycling and a low rate of battery charge from an alternator lead to sulphation of battery plates. As a result, the batteries need replacement before they reach their full life expectancy.

Battery plate sulphation is the most common cause of battery failure. Sulphate (sulphuric acid) crystals form in a normal chemical reaction when a battery discharges and recharges. The sulphate crystals attach to the battery plates and cause physical damage. Sulphates will also shake loose via our old pal vibration and float to the bottoms of each battery cell. The battery will internally short-circuit when the build-up of sulphates accumulates and provides contact across different cells.

Low specific gravity of electrolyte causes further degradation. With battery plate sulphation, the insulating film that covers the plates will affect the electrolyte by lowering specific gravity. Therefore, the chemical reaction in the battery will be unable to support enough charging current from the alternator to restore the battery charge. In other words, the decreasing battery voltage will have a tough time providing a strong discharge current to the electrical accessories (load). This exacerbates in colder weather. Furthermore, the battery will lack capacity to sufficiently power the starter motor to turn (cranking power) the engine for start-up. I realize that most of us do not ride our bikes in the freezing cold but cranking power steadily decreases with temperature drop. This progresses down until at 0° F (-18°C) where even a fully charged battery will provide only 40 percent of the cranking power of a similarly fully charged battery at 80°F (27°C).

Rejuvenating a Wet Battery

There is a procedure for rejuvenating Wet sulphated batteries. The latest rejuvenators typically use solid-state high frequency pulsing technology to raise battery cell voltages in some cases to over 15-volts. A fully charged 12V H-D battery in perfect working order usually has 14.2-volts or thereabouts. This rejuvenation action removes sulphation, reforms the negative plate and returns the battery to optimum condition with non-sulphated clean plates and a higher specific gravity electrolyte. Usually, motorcycle battery distributors have a rejuvenation tool to reenergize warranty battery returns.

Battery Storage

I was incorrectly taught to always remove a battery for storage purposes and place it on wood. The mythology is that concrete or similar substances will drain the battery. I still store my batteries on wood although I am now aware this is an old-time mechanic's superstition. It just makes me feel better. Ambient surrounding temperatures are best if warm. The conventional way to store a battery still works fine.

1. Ensure the battery has a fully charged specific gravity (1.260-1.275).
2. Store the battery in a location with about a 60° F (16° C) ambient temperature.
3. Freezing temperatures may freeze the electrolyte with resultant battery case and/or internal battery plate damage.
4. Charge the battery once a month until fully charged.
5. If the storage area has high temperatures, the battery will require more frequent charging.

However, technology marches on.

Battery Tender

A battery tender is a fully automatic battery charger. It will maintain proper electrolyte specific gravity, which is a fancy way of saying it will keep the battery fully charged.

1. Attach the battery tender to a battery that can remain in the motorcycle.

2. The battery tender switches to a safe storage maintenance voltage at the end of each automatic charging cycle.
3. Most battery tenders including the Deltran Battery Tender (www.batterytender.com) of Deland Florida use a combination of colored lights to indicate the state of charge or charging. I believe that Deltran currently manufactures the current Harley-Davidson battery tender.
4. When choosing a battery tender, I recommend one with all the available safety options that include spark free operation, continuous short-circuit protection, and reverse polarity protection.

I use battery tenders in my shop now for storage bikes. They are convenient, easy to use; reduce labor from conventional storage-charging maintenance, and perfectly safe. My Corvette's battery always drains when stored. I started using a battery tender two years ago on the Vette over a cold Canadian winter and it stays fully charged all the time now.

Amp-hour Rating

Batteries have an amp-hour rating. The amp-hour rating for your year and model Evolution or Twin Cam will be on the battery box or in the battery instructions. Since you never took the trouble to read the box or instructions, you will also find the rating in your H-D manual. Your punishment for not reading the instructions is to purchase the manual.

So, what is an amp-hour rating? A battery's amp-hour rating indicates the total amount of energy it will deliver at a constant rate of discharge over a period of 20-hours before it reaches a voltage at which it is fully discharged. We will need the amp-hour rating to perform the best test of all for a battery….the load test.

Testing a Maintenance Free Battery

There are three different tests for a maintenance free battery:

1. Voltmeter Test; battery may be fully charged or not.
2. Conductance Test: battery may be fully charged or not.
3. Load Test: battery must be fully charged!

The load test is the best, most comprehensive test for either conventional or maintenance free batteries.

Voltmeter Test

The battery may be fully charged or not. I like it fully charged.

With the battery disconnected (open circuit) perform a voltage reading with a voltmeter, recharge if the battery is below 12.6 volts.

1. If recharged, let the battery sit for two hours before the next test.
2. Redo an open circuit (battery disconnected) voltmeter test. The battery should be 12.7 volts or more. If so, proceed with a load test, described below.
3. If 12.6 volts (75% charge; 12.3 volts (50% charge); 12.0 volts (25% charge) or 11.8 volts (0% charge; dead), replace the battery.

Conductance Test

This test is an in-bike one. A conductance test requires Harley-Davidson tool HD-48053 called an ADVANCED BATTERY CONDUCTANCE AND ELECTRICAL SYSTEM ANALYZER. This test gives much information:

1. Battery condition.
2. Measures state of charge.
3. Measures the cold cranking amps (CCA).

Connect the Analyzer leads to the battery for testing. There are a possible five different test results that this cool-tool will print out:

1. CHARGE and RETEST.
2. GOOD-RECHARGE.
3. GOOD BATTERY.
4. BAD CELL-REPLACE.
5. REPLACE BATTERY. If the printout indicates a REPLACE BATTERY, the possibility remains that there may be a poor connection distorting the test. Remove the battery from the motorcycle and confirm with a voltmeter test. If passing the voltmeter test, the problem is likely a corroded or loose or improperly fitted (crimped) terminal. Check and redo an in-bike conductance test.

The Ultimate Check: Load Testing

This information applies to both types of batteries; conventional and maintenance free. Very few bike shops have a battery load tester but your local battery supplier should have one. The load tester does exactly what its name states; it places a load on the battery to see if it will respond positively. This test measures battery performance under full-current load.

1. Never load test a discharged battery because if it wasn't any good before, it certainly won't be now.
2. Therefore, always fully charge a battery for load testing.
3. Let the newly charged battery sit for an hour or more before load-testing.
4. With the load tester in the *off-position* or disconnected, connect the battery cables, positive first to the battery posts.
5. Place the load tester's induction pickup over the negative cable. Positive is usually red in color while negative or ground is always black.
6. Never apply a load test for more than 20-seconds unless trying to ruin the battery and possibly damage the load tester.
7. Loading the battery:
    a) On a Wet conventional battery; load to 3-times its amp-hour rating. In the case of a late model Evolution FLT; this will be 90amps. A mid 1990's Softail uses a 19amp-hour battery. Set the load tester to 57amps. A 2007 FLT has a 28amp-hour battery @ a 20-hour rate. Set the load tester to 84amps. In other words, consult your manual for year and model to determine the load rating.
    b) On a maintenance free AGM battery: look up the cold cranking amperage (CCA) of the battery to be load tested. Load test the battery at 50% of the CCA rating. For example; a 2007 FLT touring model battery has a CCA of 370-cold cranking amps. Therefore, load test the battery at 185-CCA
8. Apply load for 15-seconds with either methodology.
9. The battery voltage for either type of battery should read 9.6-volts or more after the 15-seconds @ 70° F (21° C). If not replace.

H-D Battery Application 1984 to 2010

Year	FLT	FXR	Softail	Dyna
1984 to 1986	66010-82	65991-82	65991-82	NA
1987 to 1990	66010-82A	65991-82A	65991-82A	NA
1991 to 1994	66010-82A	65991-82A	65989-90A	65989-90A
1995 to 1996	66010-82A	NA	65989-90A	65989-90A
1997 to 1998	66010-97	NA	65989-97	65989-97
1999	66010-97	65991-82A	65989-97	65989-97
2000	66010-97A	65991-82A	65989-97A	65989-97A
2001	66010-97A	NA	65989-97A	65989-97A
2002	66010-97A	NA	65989-97A	65989-97A
2003	66010-97A	NA	65989-97A	65989-97A
2004	66010-97A	NA	65989-97A	65989-97A
2005	66010-97A	NA	65989-97A	65989-97A
2006	66010-97A	NA	65989-97A	65989-97A
2007	66010-97A	NA	65989-97A	65989-97A
2008	66010-97B	NA	65989-97A	65989-97A
2009	66010-97C	NA	65989-97B	65989-97B
2010	66010-97C	NA	65989-97B	65989-97B

Battery Life Expectancy

In the old pre-1966 kick start days, the 6-volt batteries lasted longer than the new-fangled electric start batteries introduced on the FL/FLH models in 1965. A good, half-circle kick on the compression stroke invariably fired the beast if in tune. However, the electric-start batteries suffered much:

Battery technology even for conventional lead-antimony electrolyte ones used until the end of the Evolution improved over the years.

- The early electric-start systems were crude and many times ill-fitting. Take the poor starter solenoid, which attached on one side only on all rigid mount inner primary chaincase's until the advent of the Nippodenso starter motor in 1990. The introduction of the rubbermount bikes in 1980, mercifully mounted their solenoids on either side. Rigid mount solenoids flexed back-and-forth on their one-sided bracket stressing the system, causing parts misalignment, and expending unnecessary battery energy.
- Rigid mount bikes vibrated excessively. Vibration kills batteries dead, shaking their internal cells apart causing internal sulphation short-circuits. Rigid mounts did not receive counterbalancing until 2000 under the auspices of the Twin Cam design.

In the old days, it was common to replace a battery every season. This continued into the Evolution era where it was uncommon to get two years service life from a rigid mount electric start motorcycle. Again, vibration is the main reason.

I have seen rubbermount models get six, seven, and even eight years service from a properly maintained battery. They certainly get at least three or four years service. Twin Cam batteries last the longest because of:

1. AGM, low maintenance design.
2. Vibration suppression whether rubber mounting or counterbalancing.
3. Quality electrical components; both servicing the battery and serviced by the battery.
4. Superior parts fitment.

Neglect will obviously reduce battery life. The most common neglectful foible is not to check the Wet battery electrolyte level at least once a month *in every cell* (6); more often in very hot weather. Use distilled water to bring the electrolyte level to the upper level marking. Do not overfill. If overfilled, remove electrolyte with a hydrometer.

First Aid: Sulphuric Acid (Electrolyte)

Okay, you filled your beer bottle with electrolyte and without thinking took a swig. Or, perhaps you disconnected the battery charger before turning it off causing a hydrogen gas explosion with resultant electrolyte (acid) in your eyes or face. There really is a reason to follow safety procedures. At least, safety will be indelibly written into your psyche from this moment on.

1. Acid on your skin is washed away and diluted with water, any water whether it is dirty, clean, tap or bottled, whatever is closest. You will probably be too embarrassed to seek a medical opinion afterwards.
2. Acid in your eyes requires water flushing, lots of water for at least fifteen minutes. Do not stop after a few minutes to see if there is a burning sensation. Keep applying water. Seek medical attention as embarrassment pales before sight impairment. A swimming pool in your backyard becomes a perfect wash solution for eye and/or skin cleansing.
3. Ingesting sulphuric acid cannot be fun. Drink tons of water or milk if immediately available. Follow this up with milk of magnesia or vegetable oil, whatever is handiest. Most people have vegetable oil in their kitchen cupboard. Another piece of advice is to swallow a beaten egg. Me, I am not taking the time to beat an egg. I think this one merits a trip to the hospital but perform the first aid first or even better on the way.

I prefer the Low Maintenance Battery

The lead-calcium low maintenance battery differs from the conventional lead-antimony battery. If faced with a choice of either for my own bikes I will always choose the low maintenance battery for a variety of reasons, which are:

1. It is low maintenance as opposed to high maintenance.
2. It gives 10% more cranking power than a conventional battery.
3. I believe their service life is also longer.

Yuasa Evolution Battery Application 1984 to 2010

Wet [1] and AGM [2] Battery Application

Year	FLT	FXR	Softail	Dyna
1984 to 1986	Y50-N18L-A [1]	YB16B [1]	YB16B [1]	NA
1987 to 1990	Y50-N18L-A	YB16B	YB16B	NA
1991 to 1994	Y50-N18L-A	YB16B	YB16HL-A-CX [1]	YB16HL-A-CX [1]
1995 to 1996	Y50-N18L-A	NA	YB16HL-A-CX	YB16HL-A-CX
1997 to 1998	Y1X30L [2]	NA	YTX20L-BS [2]	YTX20L-BS [2]
1999	Y1X30L	YTX20L-BS [2]	YTX20L-BS	YTX20L-BS
2000	Y1X30L	YTX20L-BS	YTX20L-BS	YTX20L-BS
2001	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2002	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2003	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2004	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2005	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2006	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2007	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2008	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2009	Y1X30L	NA	YTX20L-BS	YTX20L-BS
2010	Y1X30L	NA	YTX20L-BS	YTX20L-BS

It has been my experience that Yuasa has been the main vendor (supplier) of batteries to Harley-Davidson through the Evolution and Twin Cam years. Some AGM batteries retrofit back into years that were originally fitted with Wet batteries. It all depends on the year of the manual. Original year manuals will specify the original fitment while sometimes later manuals that cover a number of years will retrofit back advancements such as an AGM battery for a Wet battery if size and battery post specifications are the same.

[1] A Wet (*conventional* or *spillable)* battery is a flooded (lead) sulphuric acid battery. In other words, they are traditional batteries that remain dry and uncharged and require electrolyte (sulphuric acid) to activate them.

[2] An AGM Absorbed Glass Mat Battery (*maintenance free, valve-regulated lead acid or VRLA Battery*) use lead-calcium and sulphuric acid. Advantages are that they do not leak, resist freeing and do not require any maintenance relative to wet batteries. An AGM Battery can be stored for longer periods of time without charging. They also have high power density, are vibration resistant and can be charged and discharged rapidly. These batteries come pre-charged and ready for bike installation. Do not attempt to open these batteries.

Twin Cam Charging System

The Twin Cam charging system consists of:

1. An alternator that has of two components:
    a) Stator.
    b) Rotor.
2. Regulator/rectifier.
3. Battery.
4. Ignition switch.
5. Maxi-fuse or circuit breaker.
6. Related wiring and negative ground battery cable.

The Alternator

The alternator sits inside and at the front of the primary chaincase on the right side of the motorcycle on all Shovelhead, Evolution and Twin Cam models, 1970-to-present. It consists of a rotating rotor and a fixed stator. The rotor is a steel shell with magnets placed on the inside of the outer diameter casing and fits snugly over the stator but does not touch it. The hollow stator is about 6" across, 1" or thicker, and about 1 ½" wide depending on year. It bolts to the outboard side of the left engine case around the power output flywheel shaft also known as the crank sprocket shaft. The engine's compensating sprocket assembly also known as a compensator sits on the same shaft in front of the alternator. It's inside female splines mate with and fit over the sprocket shafts outside male splines. The compensator absorbs the shocking engine pulses via a ramp and diaphragm spring methodology to protect the powertrain and specifically the transmission. The 1970 to 2006 alternator rotor and compensator diaphragm spring covers are separate. Beginning in 2007, the alternator rotor and (compensator) spring cover become one (40356-07).

The alternator rotor shell's center can also have female splines that fit over and mate with the male sprocket shaft splinage. Depending on year, it may also be a slip-fit over the sprocket shaft splines. Thus, the rotor rotates with the flywheel assembly at the same rpm via fitment on its protruding sprocket shaft if fitted with splines. If not, the pressure from the compensator sprocket assembly turns the rotor in conjunction with engine rpm. The rotor shell's magnets rotate around the stator as the rotor turns with the engine sprocket shaft creating alternating current electricity that transfers to the regulator/rectifier via associated wiring. The wiring off the stator ends with a pressure fitted plug through the outside-front-left engine casing from the primary chaincase cavity. A similar mating plug with wiring leads to the regulator/rectifier that usually mounts close by on or near the lower-front frame down tubes.

Different size spacers are usually installed on either side of the 1970 to 2006 rotor. For example on a 2003 Twin Cam, the inner thrust washer is HD-8972; there is a center sprocket shaft spacer (24008-03) and an outer spacer (35851-84). It is paramount not to mix them up. The 2007-to-present assembly only has one spacing washer (H-D 6445) on the outside. There is an internal one also (24008-03) but it would be impossible to mix them up because of size differentials.

Regulator/rectifier

Often referred to as a regulator, the regulator/rectifier properly has a double name because it performs two functions on the Evolution and Twin Cam motorcycles.

A Panhead, early-Shovelhead, or Ironhead Sportster generator-regulator charging system transfers Direct Current (DC) voltage to the battery *regulated* at a constant safe voltage that will not overcharge and boil the battery dry. Variations of rpm-speed and engine load are controlled by the regulator, hence its descriptive functional name.

1. A later-Shovelhead, Evolution, or Twin Cam alternator produces alternating current (AC), which is of no use to the needs of a DC battery. Therefore, the regulator/rectifier:
    a) Rectifies or changes the alternating current into direct current that is palatable to the DC battery and electrical system it feeds.
    b) Transfers regulated voltage at a level compatible with the battery's storage capabilities to the battery positive terminal via associated wiring.

Thus, the reader can see why the double name is more appropriate to an alternator charging system, whereas the single name use of regulator is descriptive of a previous H-D charging system that ended use on Big Twins in 1969. The Twin Cam has a series regulator, whose circuit combines the tasks of rectifying and regulating.

All modern electronic voltage regulators operate by comparing the actual output voltage to some internal fixed reference voltage. A trigger signal is applied to cause induction of the SCR (silicone controlled rectifier or regulator) and raise the output voltage to the battery when the battery voltage drops below a control point. When the battery power exceeds the regulated control point, the trigger signal interrupts to inhibit conduction of the SCR and therefore, decrease the output voltage.

Alternator Servicing No-no's

1. Never attempt to polarize an alternator. This is a prerequisite with H-D generator/regulator charging systems. Thus some mechanics and riders may think the same is necessary with an alternator system. It is not!
2. Never disconnect the regulator/rectifier connector with the engine running.
3. Do not start the engine with the alternator disconnected from the regulator/rectifier. The only exception is with specific testing recommended in your manual.
4. Never reverse battery connections. This can cause *instantaneous* damage.
5. Do not short connections.
6. Do not use an automotive high output battery charger to assist in starting.

Troubleshooting the Twin Cam Charging System

The main symptom to analyze is a dead battery. There might be a previous symptom of an overcharging battery evidenced by much hydrogen gas bubbling and electrolyte depletion. Many of these tests will be common to most or all Twin Cams but will be specific and accurate for 2009. Consult your manual for possible differences from what I write here.

Battery Inspection and Testing

By the way, replacing a battery with a new one does not necessarily equate to a good one. New does not always mean good. Many mechanics and riders alike make this misassumption much to their consternation when they look everywhere else for the problem except where the problem lies. Always perform specified diagnostics on even new parts.

1. Visually inspect the battery for corroded terminals, a loose ground, and electrolyte depletion. Refer to previous section *Battery Care.*
2. Clean corroded terminals.
    a) Connect ground.

   - b) Replace a maintenance free battery with electrolyte depletion.
3. Charge battery.
4. Test maintenance free battery via Voltage Test; Conductance Test and/or a Load Test. When doing a load test replace battery if indicated.
5. Proceed when it is certain battery meets specifications.

Battery Discharges with Inactive Motorcycle (parked)

1. Perform amperage draw test. Set the Multimeter to amps. If excessive disconnect unnecessary components.
2. Milliamp Draw Test: perform a Milliamp (one-thousandths of an amp) Draw Test. New technology brings new problems. With the introduction of onboard computers (ECM), memory radios, and other accessories may require current to maintain functioning even with the ignition in the OFF position. A milliamp draw test is required to test the continuous energy supply. Typical drains are:
   - a) Voltage Regulator: 2.0 milliamps (older models .5 milliamps).
   - b) ECM 1.0 milliamps.
   - c) Speedometer 1.0 milliamps (older models .5 milliamps).
   - d) Tachometer 1.0 milliamps (older models .5 milliamps).
   - e) TSM (turn signal module) on non-security models 1.0 milliamps (older models .5 milliamps).
   - f) TSSM (turn signal/security module) armed 3.0 milliamps.
   - g) TSSM disarmed 3.0 milliamps.
   - h) TSSM storage mode 1.0 milliamps (older models .5 milliamps).
   - i) HFSM (hands free security module) 1.0 milliamps.
   - j) Radio 2.0 milliamps.
   - k) High output amplifier 1.0 milliamps.
   - l) CB module 1.0 milliamps.
   - m) XM module 1.0 milliamps.

The milliampere battery draw test result cannot be more than the sum applicable total amperage listed. If the draw test is greater it is excessive. Consider accessories and check them for excessive drain to resolve the problem.

If using conventional testing methods, they may inaccurately condemn or okay working components and circuits. The ECM can exhibit an internal failure mode, which can result in a high parasitic current drain on the battery. Conventional tests may not detect this draw because when the battery cable is disconnected for the test, the solid state circuit responsible for the drain may not exhibit the symptom (drainage). Use a digital ammeter (multimeter) capable of reading down to one milliamp.

Battery Discharges while Riding

Perform a load test on the battery. If satisfactory perform a current draw test to ensure battery can meet demand. If there is low or no battery output, perform a regulator/rectifier ground check. Make certain the ground wire (black) is firmly affixed to its ground. If there is paint on the ground surface, scrape it off so that metal ground lead contacts bare metal.

1. Current and Voltage Output Test; perform with a load tester.
   - a) Connect the load tester to battery in bike.
   - b) Connect negative lead to negative terminal; positive lead to positive terminal; place load tester induction pickup over the positive battery regulator/rectifier cable.

  - c) Start and run engine to 3000 rpm.
  - d) Increase load until achieving a steady 13-volts Direct Current (VDC).
  - e) Never leave load tester on for more than 2-seconds or your problems are just beginning.
  - f) Current output should be 35amps to 50amps.
  - g) Furthermore, this current output should exceed current draw by at least 3.5amps. See amperage draw test above in *Battery Discharges with Inactive Motorcycle (parked)*.
  - h) After removing the load; read the load voltage test meter. If battery voltage supply to battery does not exceed 15-volts, voltage output from regulator/rectifier is okay. Proceed to *Charging System Test* below.
  - i) If voltage is higher than 15-volts, replace the regulator/rectifier.

2. Total Current Draw Test:
   - a) It is possible that the total current draw of all the motorcycle components, many listed above under the Milliamp Draw Test, can exceed the charging system output.
   - b) Connect a load tester to the battery: negative lead to negative terminal; positive lead to the positive terminal and the induction pickup (current probe pickup) over the battery negative ground cable.
   - c) Disconnect the stator alternator plug from the regulator/rectifier.
   - d) Start and run the bike to 2000 rpm.
   - e) Read the Total Current Draw with all running lights (headlight high beam on) and accessories on.
   - f) Compare this reading to one obtained under a *Current and Voltage Output Test* listed above.
   - g) The current output must surpass the current draw by at least 3.5amps.
   - h) There may be too many accessories for the motorcycle's capabilities if failing to meet or exceed this minimum surplus.
3. Charging Test: Current and Voltage Output Test; perform with ADVANCED BATTERY CONDUCTANCE AND ELECTRICAL SYSTEM ANALYZER (HD-48053).
   - a) This is an alternative test to the one immediately above using a load tester.
   - b) Connect HD-48053 leads to the bike's battery.
   - c) Follow instructions supplied with the tool. The test will decide the condition of the charging system and voltage at both idle rpm and 3000 rpm.
   - d) A printout will either state CHARGING SYSTEM NORMAL or CHARGING SYSTEM PROBLEM; if there is a problem, the printout will also display one of the following, all of which require further investigation:
   - LOW CHARGING VOLTS, the alternator is not supplying enough voltage.
   - HIGH CHARGING VOLTS, the alternator output exceeds regulator portion of the regulator/rectifier limitations.
   - INVESTIGATE VOLT OUTPUT, the 3000 rpm voltage is less than the idle voltage
4. Alternating current output test:
   - a) Disconnect regulator/rectifier from the stator plug.
   - b) Connect a voltmeter (AC) across stator connection sockets 1 and 2.
   - c) Start engine and bring rpm up to 2000 rpm.
   - d) AC output should be 32-volts to 24-volts (16-volts to 23-volts per 1000 rpm).

  - e) Repeat this test across stator sockets 2 and 3 and 3 and 1.
  - f) If output is within specifications listed above, the problem may be a faulty regulator/rectifier.
  - g) In this case, check output as explained in *Current and Voltage Output Test* above.
  - h) If any of the three tests are below 16-volts per 1000 rpm, this may indicate a faulty alternator rotor or stator.

5. Test stator for a ground:
    - a) Ignition off; disconnect regulator/rectifier from the stator at the engine case mount.
    - b) Set ohmmeter to Rx1 scale.
    - c) Connect an ohmmeter between one of the exposed stator pins and ground.
    - d) The reading should be infinity, which is no continuity. If not obtaining this reading, the stator is grounded and needs replacement.
6. Test stator for resistance.
    - a) Set the ohmmeter to Rx1 scale.
    - b) Connect the ohmmeter between two stator pins and repeat with all pins (1-2; 2-3 and 3-1). Year of bike depends on number of pins. I use 2009 FLKT touring as an example.
    - c) Ohmmeter reading for 2009 FLT touring should be .1 ohms to .2 ohms. Contrast this for a 1981 to 1988 22amp stator (29965-81B) where the reading should be .2 ohms to .4 ohms.
    - d) Consult your manual for year and model for ohmmeter reading specifications.
    - e) If no needle movement is noticeable or resistance is greater than specifications replace the stator.

Battery Drain back through the Regulator/rectifier.

There are many ways for a battery to discharge. A bad regulator/rectifier is one of them although many will not check this cause. What happens? The regulator/rectifier internal diode may let excessive voltage to pass by allowing the battery to drain through the regulator/rectifier ground. A fast way to determine if this is happening is to use a trouble light.

1. Disconnect the regulator/rectifier plug.
2. Ground the trouble light to the frame.
3. Touch the trouble light probe to one of the regulator/rectifier plugs pins and then to the other but not at the same time.
4. If the trouble light bulb lights up, replace the regulator/rectifier to resolve the battery drainage problem.
5. Retest.

Twin Cam Starter System

The electric starter system consists of:

1. Battery.
2. Solenoid.
3. Starter relay.
4. Starter motor.
5. Starter gear(s).

6. Starter button.
7. Maxi-fuse or circuit breaker.
8. Associated wiring and cables.

The Nippodenso starter motor has been in use from 1989-to-present on Evolution Big Twins and all Twin Cam motorcycles. Japanese starter motors have been used for many years on Harley-Davidson's. The Nippodenso starter motor was preceded with the Hitachi starter motor.

Pushing the handlebar starter button energizes the starter relay, which directs current from the battery via a heavy cable and wiring to the integral solenoid's pull-in winding and also into the hold-in winding to ground. A thick cable is required for a large current flow.

This sounds confusing until realizing the starter motor drive gear must be pulled into the ring gear to engage and must be held in while activated. Therefore, the magnetic forces generated by the battery current into the windings in the solenoid pulls a plunger shifting it towards the primary so the pinion gear can engage the clutch hub's ring gear. Simultaneously, the main solenoid contacts close allowing the battery current to flow into the starter motor armature field windings and to ground. Remember that an electrical circuit must always go to ground for a complete circuit.

Concurrently, the pull-in winding opens while the solenoid contacts remain closed. The starter motor activates with rotational torque that turns the clutch hub ring gear, while the duplex (two-row) primary chain dual sprocket on the clutch shell turns in tandem. The primary chain turns the engine compensating sprocket, which turns or cranks the engine over for ignition and starting. The rider releases the starter push button. If not paying attention to starter button release, the ensuing noise of pinion gear engagement with the motor running will startle the rider into lifting his or her finger off the starter button. This action reverses the current holding in the solenoid contacts and in the pull-in winding. The solenoid spring will return the plunger to its resting original position, which in turn, disengages the pinion gear from the clutch shell's ring gear.

The Starter Motor

This is a powerful electric motor that engages the Evolution/Twin Cam's clutch shell's ring gear in order to spin the engine crankshaft for ignition. As in all electric motors, the starter is composed of *armature* windings of wire that form loops, ending at the *commutator* at the opposite end of the motor's drive gear. The windings are similar to those in a generator. The armature's coil windings are mounted around the starter motor's central shaft. The shaft is supported by a bearing at either end in the outer steel encasement frame of the starter motor. Inside the outer frame are flat but rounded shoes or holders following the contour of the outer steel shell. The shoes contain the *field coils.* As we will see, the armature windings rotate within the surrounding field coils.

Four *brushes* made from carbon material attach to the field coils by wiring. They sit in a holder at the commutator end of the starter motor and rub on the commutator during starter motor rotation. The brushes are used to create electrical contact to the commutator segments and when current is fed into two of the four brushes, the current will flow through all the loops of the armature and shoe field coil windings and out the other two brushes. This current flow creates a magnetic field around each loop. As the armature turns, the loop will move to a position where the current flow reverses. This constant reversal of current flow causes the rotating armature and fixed field coils to repel each other and spin the motor. Starter motor torque power is solely dependent on the amount of current flowing in the field coils. The greater the current is, the greater the magnetic forces, who's reversing current flows drive the starter motor's rotation

The armature's copper loops and field windings are heavy enough to carry a large amount of current with minimum resistance. Since they draw heavy amounts of current, they must *not* be operated on a continuous basis for longer than 30-seconds. After cranking for 30-seconds it is wise to wait a couple of minutes to let the starter motor dissipate some of its heat. Starters heat quickly. Therefore, prolonged use can cause serious damage. A typical symptom of overheating starter motors is extremely slow, labored engine-cranking.

Starter motors fail mostly due to overheating. Rider's who inadvertently place them in a hostile, hot environment cannot expect them to last indefinitely.

1. Another mode of failure is a shorted or open winding. This exhibits itself as a *dead spot* on the commutator. If a brush lands on a dead spot the motor won't turn at all.
2. A third failure-mode is a faulty pinion gear to ring gear engagement. Sometimes the pinion assembly gets stiff or stuck due to lack of lubrication or wear.
3. Starter motor rebuilding or replacement is required for all of these problems. However, as always check to make sure the electrical connections on the starter, solenoid and battery are clean and tight. Most failures to start the Twin Cam or any other electric start Harley-Davidson are due to loose or corroded battery cable connections or low-current solenoid connections, not to faulty starters. Remember, at all times diagnosing should progress from inexpensive and easy to difficult and costly. A starter motor repair is both expensive and difficult relative to cleaning or tightening a cable, which is pretty much free.

Calculating Starter Motor Power

If I use the 28amp rated battery common to many later Twin Cam FLT touring motorcycles as an example, it is capable at 12-volts of putting out 336 watts.

Watts = amperes x volts
28amps x 12-volts =336 watts

The starter system needs all the wattage it can get to develop enough horsepower to turn the engine over for ignition. James Watt invented the arbitrary concept of horsepower.

1 horsepower = moving 550 pounds one foot in one second

James Watt also mathematically determined that one horsepower equals 746 watts. Therefore, a 28amp rated FLT battery generates almost 1/2 horsepower (336 ÷ 746 = .450) to turn over a Twin Cam engine. This will constantly start an engine in good tune without any problem. Compare this to an Evolution 19-amp rated battery that will generate about 1/3 horsepower (228 watts) to turn over its engine.

Starter Solenoid

The starter solenoid is a relay. The Twin Cam is wired so that the battery's main thick cable capable of carrying a large current connects to the starter motor windings. This cable must be switched on and off. Logically, it should route through the ignition switch for the on-off capability. Imagine the ignition switch size required to carry such current. This certainly isn't practical so a relay is necessary to perform this function. Compare the size of a heavy solenoid to a normal relay and the reader will understand that it is capable of on-off switching the large battery current.

Solenoids are electrical devices that utilize a central iron core fitted closely to the inside of a coil of wire. When the wire is energized by the battery current, the iron core will be drawn down the length of the coil. The direction is dependent upon the route of current flow. Therefore, it is simple to move the core in the necessary direction for a particular application. The solenoid's iron core is fitted with large, high current-carrying contacts so it can perform as a high-current switch. Relays are used for a variety of purposes and smaller ones may be suitable for horns etc. However, the most important relay is the starter solenoid.

The starter solenoid's very large contacts can carry the battery's full current. Its wire coil is actuated by a smaller current from the ignition switch, at which time the iron core forcefully moves down to make contact and turn on the starter motor.

In the disengaged position the drive gear is released and no current is flowing.

1. In the partially engaged stage, current from the starter switch flows through both the pull-in and the hold-in coils. Both coils draw the plunger inward to the left to engage the clutch hub ring gear.
2. When the plunger is pulled into the coil all the way, the pinion fully engages the ring gear.
3. As the ring gear is fully engaged, engine cranking begins via the primary chain and compensating engine sprocket.
4. When the engine starts, the pinion gear turns freely through the action of the overrunning clutch. This prevents the armature from also overrunning by the rotation of the clutch hub ring gear.
5. The hold-in coil will cut out and the plunger will move out, retracting the pinion and opening the starter switch.

Troubleshooting the Evolution/Twin Cam Nippodenso Starting System

Harley-Davidson manuals generally have excellent starter motor diagnostic charts for the wrench to follow through in an organized and comprehensive fashion. The charts are intimidating with first blanch. Many will give up once looking at these multi-faceted charts in their totality. I know I did many years ago. However, the trick is to just start at the beginning and do one examination or test at a time. What initially seems very complex will become logical and simpler as the reader moves through the charts. Self confidence will ensue with each passing test inexorably moving through to the solution. First let`s understand some basics that no one ever seems to explain.

Continuity; No Continuity, and Infinite Ohms Definitions

The symbol for an ohm is Ω and is named after Georg Simon Ohm. With respect to direct current an ohm measures electrical resistance. Resistance determines how much current will flow through a component. Resistors are used to control voltage and current levels. A very high resistance allows a small amount of current to flow. A very low resistance allows a large amount of current to flow.

1. Zero ohms indicate electrical *continuity* (closed circuit).

2. A resistance measurement of *infinite ohms* indicates no continuity (open circuit)

I will proceed as usual from simple and inexpensive to complex and pricey. Therefore, I will conduct tests that do not involve disassembly of motorcycle components first.

Voltage Drop

Voltage drop testing is real life testing that will overlap and diagnose some of the later specific problem analyses. It is a great way for finding poor connections. Also known as *voltage drops*; this testing will locate poor connectivity and disproportionate voltage drop.

Voltage drop will check wiring and connectors including circuit breakers and switches from the source to the destination. Sounds simple enough especially when compared to viewing the wiring mass as a whole. Furthermore, voltage drop testing measures actual voltage drop between a starting place and an end relative to the possible voltage. Use a voltmeter or a multimeter set for voltmeter function:

1. Attach voltmeter red lead to the positive side of the battery (source).
2. Attach the black voltmeter lead to the end or destination of the starter circuit, which will be the solenoid terminal from the relay.
3. Read the voltmeter while pushing the starter button.
4. An ideal reading will be 0-volts or zero voltage drop, which may also be expressed as no difference in potential. An open circuit will read 12-volts drop.
5. What indicates an excellent circuit? As I said, zero voltage-drop is ideal but less than 1-volt drop is acceptable meaning the circuit is good.
6. If the voltage drop is more than one volt, there is a problem and it will be necessary to backtrack through the connections until the source of voltage drop is found. The circuit must be sectionalized to do this and involves the same battery to sub-destination testing until the problem is isolated.

Voltage drop testing can be used on other circuits like lighting or ignition in the same way as the starter motor circuit. Always begin from the battery positive source to the final destination first.

Finding poor grounding is another bonus especially those interfered with by paint, powdercoating and hidden corrosion. Voltage drop is far more accurate than an ohmmeter resistance testing for partial grounds. An ohmmeter will read even partial connectivity leading the mechanic to a wrong conclusion. Voltage drop will expose a partial ground connection.

1. Attach the voltmeter negative black lead to best source of negative grounding, which is the negative battery terminal.
2. Attach the positive lead to the ground being tested.
3. Push starter button and read voltage drop.

On-motorcycle Starter Current Draw Test

Use an induction ammeter, which is ideal for checking low current applications such as the accessories to the electrical system. It is also useful for checking grounds and low voltage leaks. Furthermore, it is ideal to check starter motor current draw.

1. Ensure the battery has a full charge and is in good working order.
2. Conduct test with engine at room temperature with transmission in neutral.
3. Unplug spark plug wires from their spark plugs.
4. Fasten induction ammeter over the positive battery cable next to the starter.
5. Place the other lead to the *M* terminal on the starter motor.
6. Turn ignition to ON; push starter button to turn engine over while reading the ammeter.

7. Ignore the opening high current reading when first pushing the starter button.
8. The starter current draw should vary between 160amperes to 200amperes.
9. If the current draw exceeds 250amps, this will indicate a problem in the starter or starter drive. Remove the starter motor for further testing called a *Free Running Current Draw Test* commonly referred to as a *Bench Test.* The figures in items 8 and 9 are for a 2009 FLT touring model. Figures for some earlier models are lower. Consult your manual.

Free Running Current Draw Test (Bench Test)

1. The starter motor must be removed from the motorcycle for a bench test.
2. Place the starter motor surrounded by a shop cloth (rag) in a vise with copper jaws just tight enough to hold the motor without damaging it.
3. Connect a minimum 6-gauge jumper cable between the starter mounting flange and the negative post of a fully charged battery.
4. Connect another minimum-6-gauge jumper cable between the positive terminal of the battery and the positive solenoid terminal of the starter motor.
5. Connect a minimum-14-gauge jumper cable to the positive terminal of the battery and the other end to the solenoid relay terminal.
6. Place the induction ammeter over the cable.
7. Ammeter reading should be 90amperes maximum.
8. However, if the free running test indicates an acceptable maximum 90amps but the in-motorcycle starter current draw test was over an unacceptable 200amps, the problem will be a mechanical one in the engine (binding or heat seizing), the primary drive, or with the starter jackshaft.

An unacceptable free running test of over 90amps will necessitate starter motor disassembly for further inspection and/or testing. See Item 6. Starter Motor under *Starter Motor Problems: Not Turning or Turning Slowly* below.

Starter Motor Run-on

If the starter motor does not shut down when releasing the starter button:

1. Make certain the starter relay is mounted correctly and properly grounded.
2. Test starter relay for unopened contacts. Replace starter relay if contacts fail to open.
3. Test starter relay for poor (contact) returning. Replace starter relay if contacts fail to respond well.
4. Test starter switch for unopened contacts. Replace starter switch if contacts fail to open.
5. Test starter switch for poor (contact) returning caused by a *sticky* switch or relay contacts. Replace starter switch if contacts fail to respond well.
6. The solenoid spring may be worn. Replace the solenoid, which is part of the starter motor if necessary. The solenoid is not as rebuildable as the one in use with the previous Hitachi starter motor.
7. Inspect solenoid for short in solenoid coil layer. Replace solenoid if finding a short.
8. Inspect solenoid plate for stickiness or melting. Replace solenoid if heat damaged.
9. The cause may be a mechanical engagement via a badly worn ring gear on the clutch shell inside the primary.

a) Replace the ring gear. H-D parts books make no reference to a separate ring gear except for the 1998 to 2006 clutch shell. However the replacement of the whole clutch shell is expensive. The aftermarket has ring gears for every clutch shell. Upgrading to more or less ring gear teeth to improve gear reduction as the case may be is also an option.
b) Ensure the mating jackshaft pinion gear (31342-90, 31342-93, 32342-94, and 31345-06) has no damage. Replace if necessary.

Starter Motor Problems: Not Turning or Turning Slowly

1. Battery:
   a) Check battery terminals for corrosion and tightness. If corroded, clean the terminals and tighten cables.
   b) Perform load and specific gravity tests if a Wet battery and conductance and voltmeter tests if a maintenance-free battery. If discharged; recharge. If shorted internally replace the battery.
2. Wiring:
   a) Check battery connections at both ends for corrosion and tightness. If corroded, clean the terminals and tighten cables and wiring.
   b) Examine wiring at handlebar connection for shorts and poor connectivity. Repair and tighten as necessary.
   c) Check wiring from starter switch to the solenoid terminal. Repair or replace as necessary.
   d) Check starter relay for wire connectivity including the ground. Repair and tighten as necessary.
3. Starter relay:
   a) Many simply replace the starter relay since it is inexpensive and easy to replace. I also use a new starter relay but only as a tool to see if the old one is defective or not.
   b) Consult your manual for continuity test with a multimeter. Test varies by year.
4. Starter Push Button:
   Test for low voltage on:
   a) Input side indicates a bad connection from the ignition switch.
   b) Output side specifies a bad switch; replace switch.
5. Solenoid:

The starter solenoid is an electromagnetic switch that simply opens and closes the starter motor circuit. This switch comprises of *contacts* and a coil *winding* around a hollow cylinder with a moveable plunger. After pushing the starter button, the battery energizes the winding producing magnetism that pulls the plunger into the coil winding against two switch contacts thus closing the circuit. Before I get to the different solenoid problems and tests, there are a couple of important caveats:

a) The three tests must be performed consecutively and in the following order; pull-in, hold-in, and return. After learning the simple tests, the reader will see that one easily flows into the next and will not take much time at all. All three tests can be effortlessly performed in a minute or two.
b) Do not perform the tests for less than 3-seconds or more than 5-seconds.

c) Remove the starter motor to perform the following bench tests. A bench test means that the testing is done off the bike on the mechanic's work bench. Specified torque for starter motor bolts is 13 ft-lbs to 20 ft-lbs.

d) The late-1994 to 2006 coupling (60647-94) will stay on the jackshaft. Jackshaft bolt specified torque is 7 ft-lbs to 9 ft-lbs. There is no separate jackshaft per se´ on later 2006-to-present starter motors as the ring gear relocates inwards on the clutch hub towards the starter motor. A shaft still has to extend the pinion starter gear into engaging the clutch hub ring gear.

e) Solenoid Pull-in Test:

f) Use a 12-volt battery and connect 3-test leads as follows:

- Negative battery post to solenoid housing; negative battery post to solenoid motor terminal and positive battery post to the solenoid relay terminal.
- At this point, the solenoid should pull in (extend) the starter shaft forcefully.
- Repair or replace solenoid if the pull-in is weak or does not occur.
- Solenoid Hold-in Test:
- Use the same setup as with the aforementioned pull-in test. The starter shaft is in the extended position.
- Now, disconnect the negative lead to the solenoid motor terminal. The shaft should remain in the pull-in (extended) stance.
- Repair or replace solenoid if the shaft does not remain extended in the pull-in (extended) location.

a) Solenoid Return Test:

b) Connect the test wire leads the same as with the pull-in check.

- Now disconnect the solenoid relay terminal positive test lead.
- If the extended shaft returns to its original position, the solenoid is okay.
- If the shaft does not retract, repair or replace the solenoid.

6. Starter Motor:

The description of the components that make up a Nippodenso starter motor are the same as I describe under the section entitled *The Starter Motor* above. It may be necessary to briefly review this small section before proceeding. Disassemble the starter motor. A lot of stuff I am about to describe is old-time mechanical rebuilding techniques. There is nothing wrong with this as it was done this way for a very long time but it is labor intensive and requires specialized tools. Today, the technician simply replaces the starter motor if it does not meet test specifications. A dealership that has been in business for 50-years will have the tools but I doubt young technicians will know how to use them. You need an old-time dealership with greybeard mechanics for this stuff.

a) Inspect the four starter motor commutator brushes. Minimum brush length is .443" (11mm). Replace all four brushes as a set if necessary even for only one brush failing to meet specified length. It is necessary to replace the field coils and the brush holder to replace all four brushes since 2-brushes attach to the field coils (one each) and the other two brushes attach to the brush holder.

b) Inspect brushes for chips. Replace the set of four if one or more brushes are chipped.

c) Inspect poor contact of brushes to commutator. Check brush spring tension. Replace if necessary.

d) Commutator should be a bright copper color. If burned brown or black, correct on a lathe. Manuals also say that the armature (31515-90) can be replaced. This is too expensive to do as a response to a burned commutator an integral part of the armature. Many times, crocus cloth will do the job. Do not use metallic paper like emery cloth because of the starter motor running magnetic fields.

e) Check runout of the commutator by placing the armature in a lathe or H-D flywheel truing jig. A commutator with more than .015" (.38mm) runout will require machining on a lathe.

f) Commutator diameter cannot be less than 1.14" (30mm). Replace the armature if the commutator fails to meet minimum diameter specification.

g) A commutator is a series of conducting copper sections separated by mica. Each conducting segment on the armature of the commutator is insulated from adjacent segments by the mica insulator. The mica insulation must be undercut square relative to the conductive copper portions.

h) On a Nippodenso starter motor the mica undercut depth must be more than .008" (.20mm). There is a mica undercutting machine to do this procedure but they are far and in between.

- Simply use a 3-sided file to start the cut.
- Use a hacksaw blade to finish the undercutting to a depth of .0312" (.79mm).
- Do not leave a thin layer of mica against the copper walls above the cut-depth. The mica must be cut away totally and square to the specified depth.
- Remove burrs with crocus cloth and blow clean.

a) Test for a shorted armature on a tool called a *growler.* Most shops send their armatures out for this specialized test. Replace or repair shorted armatures.

b) Test for a grounded armature with an ohmmeter.

c) Touch one probe to any commutator segment (not mica undercut).

- Touch the other probe to the armature core, which is the thickest diameter as well as the longest armature section.
- The reading should be infinite ohms (no continuity or an open circuit).
- If there is any continuity (closed circuit), the armature is grounded and must be repaired or replaced.

d) Test for an open armature with an ohmmeter.

e) Check for continuity between all commutator segments.

- All test points should indicate 0-ohms (continuity).
- Replace the armature if there is no continuity at any test point.

f) Test for a grounded field winding with an ohmmeter.

- Touch one probe to the starter motor housing frame called a starter yoke assembly.
- Touch the other probe to each of the two brushes that attach to the field winding.
- The reading should be infinite ohms (no continuity).
- If there is any continuity at the brushes, the field winding is grounded and must be replaced.

g) Test for an open field winding with an ohmmeter.

- Touch one probe to the field wire.
- Touch the other probe to each of the two brushes attached to the field coils.
- All test points should indicate 0-ohms (continuity).
- Replace the starter yoke assembly if there is no continuity at any test point.

h) Test the brush holder insulation with an ohmmeter.

- Touch one probe to the holder plate of the brush holder assembly (31518-90).
- Touch the other probe to each of the two positive insulated brush holders, which contain brushes.
- The reading should be infinite ohms (no continuity).
- If there is any continuity at either brush holder, the field coil/brush holder assembly must be replaced.

i) Inspect the armature support ball bearing (H-D 8883). Replace if damaged.
j) Inspect the reduction gears for wear or damage. Replace if worn or damaged.

Starter Jackshaft (1989 to 2006)

The starter jackshaft sometimes called a Bendix drive is the connector between the starter motor and the clutch shell ring gear. It transfers the rotational torque from the starter motor through this mechanical assembly to the ring gear turning it clockwise with its clutch shell:

1. The clutch shell also has a dual sprocket affixed to it.
2. A connecting dual-link primary chain rotates on the clutch shell sprocket.
3. The primary chain transfers the rotational torque to the engine compensator sprocket.
4. The turning compensator sprocket attaches to and turns the flywheel left-side sprocket shaft.
5. The flywheel crank turns, raising and lowering the pistons while spark ignition occurs to fire the engine.

Starter Jackshaft Assembly Components 1994 to 2006.

1. There is a bushing in the inner primary cover that guides and supports the jackshaft on its inboard side from 1994 to 2006 (33445-94, 33445-94A). This bushing presses into its inner primary bore flush with the bore's boss to between .010" to .030" below the boss. The amount is different in diverse manuals. I prefer the .030" dimension.

2. There is another 1994 to 2006 bushing in the outer primary that guides and supports the jackshaft on its outboard side (33446-94, 33446-94A).
3. There is a 1994 to 2006 seal (HD-12066) behind the inner primary jackshaft bushing that prevents oil from the primary chaincase leaving its confines.
4. The actual jackshaft components are: the HD-4358, HD-4358A screws (1994 to 2006) that I call a jackshaft bolt is a long and skinny. They have a hex bolt head and are made of Grade 8 steel, which is exceptionally strong. They need to be since all are in the neighbourhood of 5 ½" long and thin. Initial specified torque for both jackshaft bolts is 7 ft-lbs to 9 ft-lbs.
5. Next is a lockplate (33126-94) that ensures the HD-4358, and HD-4358A screws (bolts) stay secure and do not back off. Make certain that the lockplate tab does not extend beyond the outside diameter of the pinion gear's round journal segment. If it does, it will damage the outer primary bushing as well as causing the jackshaft to bind in the bushing.
6. Next is a thrust washer (31430-94) for the lockplate to abut against.
7. Next is the pinion gear (31342-94), which goes through some extra changes from 1989 to 2006 becoming much stronger along the way. The pinion gear is two-stage with the smaller gear section engaging the coupler while the larger gear segment engages the clutch shell ring gear when directed.
8. Following the pinion gear is the pinion gear spring (33449-94). This spring separates the coupling from the pinion gear when not engaged.
9. The following retaining ring (H-D 11248) sits in a groove in the coupling. The retaining ring ensures the coupling bottoms out and is prevented from excess sliding movement. The early retaining ring (H-D 11183) positions differently in its coupling whereas the later HD-11248 retaining ring sits more to one end of the later couplings. With any of the three different style couplings, *the end closest to the retaining ring must face the starter motor.* If not, and the coupling is reversed by an errant mechanic, the coupling will contact the inner primary and the pinion gear will fail to engage the clutch shell's ring gear.
10. The coupling (60647-94) connects the pinion gear and the integral gear on the extension shaft (jackshaft) when activated.
11. The extension shaft, which is Harleyese for the jackshaft (33127-94), is an attachment piece that holds everything together, has a fixed coupling gear, provides a locking groove at one end for the lockplate and a spline at the other for another coupling to attach the jackshaft to the starter motor's rotational torque.
12. Next is a part common to all 1989 to 2006 Nippodenso jackshaft assembly's, an HD-11182 retaining ring that combines with the other coupling (31553-94A), which connects to the starter clutch's splined shaft (31664-94). The 1990 to 2006 coupling is longer than the 1989 coupling. The 1990 to 2000 coupling's counterbore must face the jackshaft.

Starter Jackshaft Binding.

If the jackshaft is binding, remove the jackshaft bolt HD-4358 or HD-4358A as the case may be. Apply 242 Loctite and torque to only 3 ft-lbs to 5 ft-lbs down from the originally specified 7 ft-lbs to 9 ft-lbs.

Starter Clutch & Solenoid Repair Kits

There are two component parts that wear out. The first is the solenoid copper contact points with the mating copper contact washer on the end of the solenoid plunger. The second is the starter clutch itself, which is not part of the solenoid but an extension of it.

Application	**Big Twin**		**Sportster**	
	Starter clutch	Contacts kit	Starter clutch	Contacts kit
1965-1988 [1]	31442-65A	714465-85T	NA	NA
1989-1990 [2]	31544-90	31608-90	NA	NA
1991-2006 [3]	31663-90	31604-91	NA	NA
Early-2007 [4]	31604-91A	31631-06	NA	NA
2007-to-present [4]	31681-07	31631-06	NA	NA
1967-1980 XL	NA	NA	31442-65A	714465-85T
1981-1988 XL	NA	NA	31567-81	NA
1989-1990 XLH	NA	NA	31567-81	31605-90
1991-94 XL 883	NA	NA	31556-91	31605-90
1991-94 XL 1200	NA	NA	31556-91	31603-91
1995-2003 XL	NA	NA	31556-91A	31603-91
2004-to-present	NA	NA	31556-91B/31328-91	31603-91

The starter clutch contains springs and bearings inside that will allow it to rotate one way but not the other. When the springs break, the unit will turn both ways and become non-functional. The symptom is a high pitch whine when pushing the starter button. Starter clutches and solenoid repair kits are also available from the aftermarket. In fact up until 1988 repair kits were only available from aftermarket suppliers like Accel. Sportster started using the Nippodenso type starter motor-solenoid in 1981, eight years before the Big Twin.

[1] Shovelhead and Evolution Big Twin.

[2] Evolution.

[3] Evolution and Twin Cam TC88.

[4] Twin Cam TC96, TC103, and CVO 110.

Electrical Future Begins in 2011

The Softail is the new guinea pig for the Harley-Davidson Local Area Network and the Controller Area Network:

1. Manages and coordinates various modules.
2. Eliminates some modules.
3. Reduces wiring gauge.
4. Trims down wiring number.
5. Shrinks wiring harness bulk.
6. Does away with most fuses and relays.

This is great stuff; a little intimidating at first but will eliminate many potential problems. This system will certainly spread to the whole H-D lineup.

Handlebar Control Switches

Handlebar control switches have new added functions and are sealed:

They use HDLAN (CAN) bus technology. HDLAN is the abbreviation for Harley-Davidson Local Area Network. CAN in this case is not the acronym for Canada but for Controller Area Network. It drives me nuts when I read information that is designed to go over my head and I don't have a clue about because no one explains the acronyms.

1. A Trip mode and a Hazard Light control is added to the handlebar switches; Trip to the Horn button and Hazard to the Starter button by converting them to a rocker switch like a Hi-LOW or RUN-OFF rocker.
2. The new handlebar control-switch units generate HDLAN messages as opposed to making traditional circuit connections.
3. The handlebar ground necessary for completion of all electrical circuits on a non-HDLAN system eliminates whether via a spring (locates in handlebar riser mount on some models to complete ground) or wire as it is no longer necessary with this system.

HDLAN (Harley-Davidson Local Area Network)

1. HDLAN is simply a data network that links the:
    a) ECM (electronic control module) that is the master control.
    b) ABS ECU.
    c) BCM (Body Control Module), which I will describe.
    d) Handlebar controls.
    e) Instrument cluster.

It is really cool once you absorb this stuff as technology marches on.

HDLAN is a 2-wire system that bases on the automotive CAN (Controller Area Network) bus technology.

CAN bus Technology

What does CAN bus technology mean? Here we go! CAN bus is an automotive communication standard that now has use on a Harley-Davidson. Communication will not continue if:

1. Either wire is shorted to power; the system will go into fail safe mode.
2. The CAN wires short to each other.
3. The CAN low wire shorts to ground, the system will not operate normally because the low wire is not a ground circuit but a return voltage circuit to complete the loop with the CAN high data line. The communication line is a loop between computers. There can be more than two computers. This type of data line can have up to 6 computers.

CAN will operate in extremely harsh environments:

1. Data consistency guaranteed.
2. It uses error correction and confinement.
3. Helpful in noise critical environments like Harley-Davidson.
4. High speeds of up to 1 Megabit per second providing real-time communication.

BCM (Body Control Module)

Consult the 2011 H-D manual for BCM replacement and service procedures. I will describe some procedures in the next section, *Digital Technician II: Modern Diagnostics.*

1. The Body Control Module (BCM):
    a) Reduces wire gauge (thickness), number of wires and thus the wiring harness bundled dimensions.
    b) Gets rid of high current loads on the ignition switch and other switches.
    c) It has automatic solid state short circuit protection that eliminates and replaces a majority of the fuses and relays.
    d) Replaces the TSM (turn signal module) and the HFSM (hands free security module). In fact the BCM integrates all the tasks of the TSM, TSSM (turn signal security module) including turn signal control, bike-tip-over shut-down function, clutch-neutral-interlock, and security systems. Traditionally, only the engine shuts down in a tip-over situation. The BCM will shut all electrical systems down except running lights in the case of a tip-over.
    e) Integrates the security system with all lighting system functions.
    f) The BCM controls the horn, headlight, the starter solenoid, and P&A (parts and accessories)
    g) Allows the use of LED (light emitting diode) turn signals without an extra module.
2. The HDLAN (Harley-Davidson Local Area Network) BCM and all other modules are always connected to battery power.
    a) The BCM connects to the ignition switch.
    b) The BCM assumes ON mode and all HDLAN components will communicate status when the ignition switch resistance (R) reaches 200Ω (ohms).
    c) The Accessory switch positions at 800Ω.

Headlight High Beam

High Beam headlight operation:

1. When the rider pushes the high beam rocker switch, the BCM receives this *message.*
2. The BCM then connects battery power to the high beam bulb.
3. At the same time the BCM sends a message to the instrument cluster to light up the high beam indicator icon light.
4. Traditionally, the headlight current would have passed through the handlebar switch or the ignition switch but *no more.*
    a) If the high beam light bulb blows, the low beam will automatically turn on.
    b) If the high-low beam switch goes south, the low beam will automatically turn on.

Starter Motor Restriction

The starter motor will only activate for 10-seconds at a time to prevent overheating. The BCM protects us from damaging our rides. It also disables the starter activation when the bike is running. Furthermore, the headlight and non-essential electrical loads turn off during engine cranking thus assisting the starter motor power.

Horn Honking Limited

The horn will only sound for 10-seconds at a time to prevent horn damage. Road rage will suffer on this feature.

The horn will also honk to warn the rider/mechanic if reversing the battery connections during service indicating a reverse polarity.

Voltage Excess Curb

If voltage exceeds 18vdc (volts direct current), the BCM will shut the bike down to protect the system from damage.

What Does HDLAN Do?

HDLAN is simply a data network that links the:

1. ECM (electronic control module) that is the master ignition and EFI fuel delivery control.
2. ABS ECU.
3. BCM (Body Control Module).
4. Handlebar controls.
5. Instrument cluster.

HDLAN is a 2-wire system that bases on the automotive CAN bus technology. It is really cool once you absorb this stuff as technology marches on.

Odometer Display Expands

The odometer display now allows for the showing of more icons (characters) with better readability; a bigger 16-segment LED display replaces the current 7-segment LED display. There are individual indicator lamps for diagnostic codes and also the:

1. BCM.
2. ABS ECU.
3. ECM.
4. Low fuel light.

2011Digital Technician II: Modern Diagnostics

The Softail models with HDLAN (H-D Local Area Network) lead the way with a new midyear level of evermore sophisticated modern diagnostics that expands to include the majority of electrical circuits.

1. There are 130 new Diagnostics Trouble Codes (DTC); this facilitates accuracy and a faster diagnosing of electrical system problems.
2. With the 2010 and earlier Softail systems as well as 2011 Touring, Dyna, and Sportster; bike shutdown or the loss of multiple motorcycle functions will occur with a variety of system failures. The 2011 Softail system has the capability to preserve motorcycle function and safety when specific system failures happen.
3. Short circuit protection expands to all power outputs with the ability to self recover once the short is fixed. Current fuses do not allow this opportunity.

4. However, Parts & Accessories (P&A) protection is provided with a separate 15amp constant battery circuit. This circuit(s) has an easy access diagnostic connector.
5. There is a separate 15amp solid state driver that provides automatic protection for Parts and Accessories devices.

TechLink

TechLink is an interface device for Harley-Davidson / Kent Moore Digital Technician.

Since its introduction about six years ago, Digital Technician (I) has been the primary diagnostic tool for all Harley-Davidson dealers globally. It was and continues to be a giant leap forward for Harley-Davidson.To stay on the leading edge of diagnostics, Harley-Davidson and Kent-Moore are introducing an updated version of Digital Technician II. This new system will allow Harley-Davidson dealers to further improve efficiency, increase revenue by cutting out aftermarket dealers thus expanding service departments, vastly improve service technical knowledge, and make the authorized dealer look good and the only game in town in the customer's eyes. The Digital Technician II system consists of the following main pieces of hardware:

1. A Fully Rugged or Semi Rugged (option choices) Laptop Computer.
2. Existing CF50/CF51/CF29 Digital Technician I models can be reused for the time being although modification/upgrades like extra memory will be required. They will be obsolescing soon as technology marches on.
3. A Handheld Computer Device.
4. Two Vehicle Communication Interface Devices (TechLink).
5. Digital Multimeter.

The Digital Technician features:

1. User-friendly Graphical User Interface (GUI) screens for quick access to any part of the software.
2. An Internet connection where the Digital Technician is updated with the latest service information, diagnostic procedures and calibrations through auto-sync sessions with Harley Intranet (a separate restricted use Internet).
3. Communicates to later equipped ECM Harley-Davidson's using the TechLink interface device.
4. Isolation Diagnostics utilizing diagnostic flowcharts integrated with electronic service manuals and data readings.
5. ECM Flash Reprogramming with selected ECM calibrations stored on the hard drive, which can be downloaded to the motorcycle instead of using Scanalyzer cartridges.
6. Here's a new one, a Vehicle Birth Certificate, whereby vehicle data and original electronic configuration can be recorded and filed for future reference by service and sales personnel.
7. Records motorcycle operating data for diagnosis of intermittent problems using TechLink and the Road Test Kit. Intermittent problems have driven customers and technicians nuts forever because the fault always seems to disappear when the mechanic checks out the bike…no more. The Road Test Kit will go a long way to resolve these annoying intermittent issues.
8. Motorcycle diagnostic information and test results can be saved and/or printed for customers.

Why is the Digital Technician I being replaced with the Digital II Technician?

The original Digital Technician (DT or DT I) is very slow, and the Windows 98 Operating System is no longer supported by Microsoft. As Harley's continue to develop, the diagnostic tool hardware requires support updates (example, TechLink) no longer feasible with the original Digital Technician.

The early version of Digital Technician II (DT II) was actually launched in July 2007 for the 2008 model line-up but continues to grow with new sophistication and diagnostic capabilities as exampled by the 2011 version. DT II will still perform all necessary diagnostics etc. for legacy bikes originally serviced by Digital Technician I. However, DT II will be the only software updated with the latest diagnostic information for 2008-to-present motorcycles.

Furthermore, Digital Technician II is an integrated diagnostic system. It utilizes wireless for motorcycle and Internet broadband communication and USB for peripheral tool communication.

2011 Digital Technician II (DTII) Tools

1. Motorcycle Diagnostic Cable (HD-48650-9) is included with DTII software and has a 2nd connector for use on 2011 Softail models with HDLAN.
2. Breakout Box (HD-50390) will adapt to future models with changing harness leads from the breakout. The meter leads connect directly to the box test ports.
3. TechLink II AC power is used with Guided Diagnostics. Read the words and think about individual meanings so as not to get lost in the new jargon. Guided and diagnostics means that the technician/mechanic will be led through the diagnostic process. It also has use with:
   a) Buell 1125 ECM reflash.
   b) Fuel pump disabling during vehicle setup.

It is necessary to disconnect when changing TechLink II to another bike.

HDLAN New Functions

There are new icons in the Status Area:

1. The icon *Turns Fuel Pump Off* is a picture of a gas station fuel pump with a line through it. This indicates the motorcycle EFI fuel pump is disabled. The fuel pump will turn ON as soon as:
2. The technician navigates to another screen, using Active Diagnostics.
   a) Cycling the ignition (turning switch on and off).
   b) Loss of TechLink communication with the motorcycle.
3. The icon *Toggles Headlamp OFF/ON* is a picture of a Harley with a cross through it. This indicates the motorcycle EFI headlight is disabled. The headlight will turn ON as soon as:
4. The technician navigates to another screen, using Active Diagnostics.
   a) Cycling the ignition.
   b) Loss of TechLink II communication with the motorcycle.

DTII Diagnostic Information

1. As in previous years, Diagnostic Trouble Codes are diagnosed in the order of importance.

2. The Diagnostic Procedure Picture lists the possible causes of a problem. Each potential cause is grayed out if probable cause is negated by pinpointing measurements.
3. The same picture will show the pre-condition(s) necessary to make the current *possible cause* diagnostic measurement. For example, if the picture is measuring a *Power Wire Open* Possible Cause, then the Test Conditions will list *Ignition On* and *ECM Connected.*

Vehicle Setup Screen

HDLAN procedures are found on the Toolbox/Vehicle Setup's *Vehicle Setup Screen.* The technician will be led through the necessary steps once a tab is chosen on the Setup Screen. The various tabs are:

1. AFV Reset (Alternative Fuel Vehicle).
2. PIN.
3. Active Exhaust Control.
4. ACR (Automatic Compression Release).
5. BCM Customization (Body Control Module).
6. Instrument ABS TellTale.
7. Module Replace.
8. Keyless Ignition Option.
9. Fuel Pump Disable.

HDLAN Electrical Module Replacement Procedures

Replacing the Body Control Module (BCM); this is the most complicated procedure so we will do it first and then it is all downhill for the rest. The technician is easily led through all the steps. Navigate the following tabs and follow the instructions from the Toolbox/Vehicle Setup: Vehicle Setup screen:

Set PIN.

1. Module Replace. This eliminates a 10-minute wait.
2. BCM Customization tab.
3. Set ABS configuration. This simply configures whether there is ABS or not on the particular bike being serviced.
4. BCM Turn Signal Customization.
5. Program FOBs.
6. BCM Customization\Lighting tab.
7. Set Running Light Configuration.
8. Set Stop-Turn-Tail Lamp options.

Vehicle Setup: Toolbox/Vehicle Setup: Vehicle Setup screen: Body Control Module customization indicates:

1. Service Mode.
2. Sidecar / TriGlide
3. Third party security via remote immobilization indicates whether the hardware is installed. This is on Brazil bikes only. It is important to select this feature when the hardware is not installed as in all non-Brazil HDI bikes as it will disable the motorcycle in question.

Vehicle Setup: Lighting Setup: click BCM Customization tab: click Lighting Tab on the Toolbox/Vehicle Setup screen:

1. First follow the steps when a BCM is replaced or turn signals are relocated. The technician is led through the following:

    a) Turn Ignition ON.
    b) Turn ON 4-way Hazard switch.
    c) Count 10 (or more) flashes.
    d) Turn OFF 4-way Hazard switch.
    e) Verify Turn Signal operation.
2. Proceed to the Stop-Turn-Tail Lamp option.
3. Then go to the Running Light Configuration and select option desired.
4. Now, set the running light to ON or OFF while the IGN (ignition) is in the Accessory Position.

Vehicle Setup: Toolbox/Vehicle Setup: Vehicle Setup screen: configures ABS:
Go to Instrument ABS TellTale.

1. Select the Update Instrument button at the bottom of the screen to configure the ABS TellTale lamp when replacing a speedometer or tachometer.

Vehicle Setup: Keyless Operation: Keyless Ignition Option on the Toolbox/Vehicle Setup screen:

1. Once in Keyless Ignition Option, the screen will give the following instructions:
    a) Verify existing Ignition Switch hardware is removed (see below for this procedure).
    b) Connect A/C Adaptor Power to TechLink II.
    c) Connect TechLink II to vehicle (no ignition power needed).
    d) Run / Stop switch to RUN position.
    e) Select Enable Keyless Ignition button (at the bottom of the screen).
    f) Toggle the Run / Stop switch.
    g) Remove A/C Adaptor Power from TechLink II.

If the motorcycle is inadvertently configured as keyless when there is an ignition switch, perform the following:

1. Turn the Ignition switch ON.
2. Turn Run switch ON.
3. The BCM will now *learn* that the bike has an ignition switch.
4. Finally, turn the Ignition and Run switches to OFF.

HDLAN Model Fault Codes

Data for the previous 10 Diagnostic Trouble Codes (DTC) is retained on the screen for Technician referencing under *DTC Extended Data* tab. The top portion of the screen is the Odometer History and Cleared Codes (DTC's). Scroll down the screen to view the DTC Extended Data by Module; example, ABS or ECM.

Look under the DTC *Data Recorder* tab for more information. The ECM will record data for 5-seconds before the last Diagnostic Trouble Code for referencing. Push the *Download File* button to retrieve a record of this information.

Conclusion

Whew! This is certainly tough stuff on first exposure but I think the reader will agree that understanding comes easier after reading the last sections a few times and absorbing them. In fact, it opens a wonderful new world of mechanics that has so many possibilities not available before. To me, it is very exciting stuff. I love the past and still ride Flatheads to Evolutions but I don't want to be exclusively stuck in the past either. I want the best of all worlds for I am not any dinosaur but an Adaptasaurus.

CHAPTER XII

The 2007-to-present TC96 Engine

I would like to say that the TC96 is a pleasure to ride in light of my extensive previous Harley-Davidson experience.

I discuss in previous sections, TC96 horsepower and torque, especially as it relates to the supercharged primary reduction ratios, and the superb gear-matching Cruise Drive 6-speed transmission. The reduction of engine rpm by as much as 11% in 6th gear is also evident in 4th and 5th passing gears. I will also not replicate other previously discussed new components like the one piece compensator-alternator rotor, charging upgrades, outboard clutch sprocket, automatic primary chain adjustment, and starter motor engagement improvements.

I also cover TC96 Engine Management System changes with Stoichiometric AFR, closed loop EFI, idle temperature cool down, injector angles, and throttle body size increases at length elsewhere in this book and in Volume II: *Performancing the Twin Cam.*

Ignition Timing and Spark Plugs

The 2007 TC96 and the 2006 Dyna's ignition timing advances 12-degrees to achieve a little more power.

Spark plug inspection service intervals (read replacement), increases to 20,000 miles (32,000 km.) Increased intervals are normal for other vehicles but looking at H-D historically, the old Dawgs amongst us, find this remarkable because we can remember the days when a new plug fouled and needed replacement before we could even kick start the ornery old machines to life. Leaded fuel ensured lots of fouling, as did the inefficient hemispherical head designs.

Big Bore, Stroke, Swept Volume, Piston Speed, and Compression

Harley-Davidson has increased the Twin Cam from 88 cubic inches (1450cc) to 96 inches (1584cc) in 2007. Why 96" instead of 95 inches achieved safely and simply by increasing the stock TC88 piston bore from 3 ¾" to the very safe and reliable 3 ⅞". Increasing bore to achieve more cubic inches does not affect reliability since piston speed remains the same as the stock configuration. Bigger bore is the safe way to more cubic inches.

Comparing Popular Engine Statistics

The chart compares some popular bores and strokes.

Compression may vary depending on pistons used and heads. Shown is the lowest compression where applicable. There may be options to raise compression further.

	Engine	c.i size	cc size	Bore	Stroke	Compression
H-D	TC88	88c.i	1450cc	3 ¾"	4.000"	8.8:1
H-D	TC95	95c.i.	1550cc	3 ⅞"	4.000"	9.4:1
H-D	TC96	96c.i.	1584cc	3 ¾"	4 ⅜"	9.2:1
H-D	TC103 Big Bore	103c.i.	1690cc	3 ⅞"	4 ⅜"	9.8:1
H-D	TC103 Trike	103c.i.	1690cc	3 ⅞"	4 ⅜"	9.6:1
H-D	FLHTK 2010	103c.i.	1690cc	3 ⅞"	4 ⅜"	9.7:1
H-D	TC110 Big Bore	110c.i.	1800cc	4.000"	4 ⅜"	9.3:1
H-D	CVO 110 2007-08	110c.i.	1800cc	4.000"	4 ⅜"	9.3:1
H-D	CVO 110 2009-10	110c.i.	1800cc	4.000"	4 ⅜"	9.15:1
H-D	TC113	113c.i.	1852cc	4.060"	4 ⅜"	10.5:1
S&S	Hot Set Up	100c.i.	1639cc	4.000"	4.000"	10.1:1
S&S	Hot Set Up	106c.i.	1737cc	3 ⅞"	4 ½"	10.1:1
S&S	Hot Set Up	116c.i.	1901cc	4.000"	4 ½"	10.4:1
S&S	Hot Set Up	124c.i.	2032cc	4 ⅝"	4 ⅝"	10.8:1
S&S	X-Wedge	139c.i.	2278cc	4 ½"	4 ⅜"	varies

Notice that the S&S 100c.i. engine is a *square* motor, revered by past generations of mechanics. Square is when the bore and stroke are the same, in this case 4.000". The X-Wedge is a 56^0 V-twin, 3-cam engine driven by serpentine belts. It comes in configurations of 110 cubic inches to 139 cubes utilizing strokes of 4 ⅛" to 4 ⅜" with bores from 4 ⅛" to 4 ½ inches.

Stroker

However, the stroke increases .375" or ⅜" on the 2007-to-present TC96 models from the 1999 to 2006 TC88 4.000" stroke to 4.375" or 4 ⅜" to achieve the larger displacement. The TC96, soon to be eclipsed by first the CVO 110 and then the TC103 models, is the largest H-D engine to date. The stock TC96 is technically a stroker when compared to 2006 and earlier models.

Compression increases to 9.2:1 from 8.8:1 due in part to the stroke increase.

The position of the crank pin is closer to the rim to give a longer stroke on the TC96 engine. Each piston's greater swept volume is responsible for four more cubic inches. The swept volume or engine displacement is due to each piston traveling $^3/_{16}$" further up the cylinder and $^3/_{16}$" lower in the cylinder for a total of ⅜" of an inch more travel. This of course equals the stroke increase from 4.000 inches to 4 ⅜ inches.

The fact remains that a more reliable engine would have resulted by using a bigger bore than an increased stroke. However, the stroke increase is a safe one as far as strokers go.

Big Bore

The new Twin Cam 96 has the same stock bore of 3 ¾" as the TC88. Therefore, the TC96 can be increased to 103 cubic inches simply and safely by increasing the bore to 3 ⅞". Exactly the same procedure is followed as with the TC88 when boring it out to 95 cubic inches on all 1999 to 2006 Twin Cams. A new cylinder kit purchase is not required. *The stock cylinders can be bored out to fit the new bigger pistons just like on earlier models.* The stock cylinders are the same as the big bore cylinders marketed by the Motor Company except for being bored out to the larger size. However, the same piston kits cannot be used because the pistons are made shorter with relocated wrist pins to accommodate the increased stroke of ⅜".

I think the reason that big bore is not used to attain the stock factory 96-inch increase is that it would have eliminated a sure to be popular 103c.i.upgrade for dealer up-selling.

Piston Speed

Piston speed increases in the TC96 because the additional piston travel must occur in the same time. Increased speed equals more heat, which creates more stress and wears out parts faster. Heat is the enemy. This discussion is to educate the reader of the implications of the new stroke changes as opposed to big bore. In the big scheme of things the stroke increase of ⅜" is not a radical one that should not concern anyone except possibly the high milers.

Cams

The TC96 cams upgrade to a new five-piece version.

The separate pieces are the camshaft, two cam lobes, sprocket, and a cam journal end press fit bearing race.

1. The cam lobes are made of the steel that works best in the application for this new design.
2. The bearing surfaces on the cam journal supporting ends are formed from steel that has the best wear characteristics for that function.
3. The cam journal ends are bigger for better support. The rear inboard journals are now 1.00" in diameter as opposed to the 1999 to 2006 TC88 cams of .875" diameter. Once again, the 2006 Dyna Glide is the exception and uses the new 5-piece cams.
4. Outboard cam journal size also increases because of the lack of traditional bearing use and the utilization of parent support material bearings in the cam support plate.
5. The primary and secondary cam-timing-chain sprockets are also narrower and different from earlier cams in order to mate with the new roller chains.

Comparative Torque (ft-lbs @ rpm)

Engine	Dyna Torque	Shovel FLH	XL
1200	NA	65@3200	
Ironhead	NA	NA	52@3800
883	NA	NA	53@4300
1200	NA	NA	72@3500
Evo 1340	82@3600	NA	NA

TC88	85@3000	NA	NA
TC95	95@3750	NA	NA
TC96	92@3000	NA	NA
TC103	108@4000	NA	NA
TC110	113@4000	NA	NA
TC113	117@4000	NA	NA
S&S116	128@3500	NA	NA
S&S124	137@4100	NA	NA

These figures are approximate and for comparative purposes only. For example

H-D rates the CVO Screamin' Eagle 110 Road King at 115 ft-lbs at 3000 rpm

Engine measured torque will be higher than rear wheel torque. Variables like compression, ignition, EFI, carburetion, clutch transfer efficiency; exhaust etc. will move the torque ratings up or down. Manufacturers will naturally publish performance statistics for their products in the most favorable light possible. Always read the fine print. What exactly is measured?

Flywheel Runout

Flywheels

The flywheels press together on all Twin Cam engines. Predecessor engine flywheels hold together via crank pin nuts. The sprocket shaft (power output) and the heavier left side flywheel are cast together as is the pinion shaft and the right side (pinion), flywheel.

- All 2007 Big Twin sprocket shafts follows the 2006 Dyna design change in multi-splining the end where the compensator and alternator rotor package slides onto the sprocket shaft with its mating multi-splines.
- This multi-splining (24 splines) replaces the ten wider ⅛" splines used on all Harley-Davidson's from circa 1955 to 2006.
- As it stands, the 2006 Dyna and 2007-to-present Twin Cam 34-tooth compensator engine-sprocket components cannot retrofit to earlier Big Twins. Nor can the earlier mechanism fit with the new multi-spline sprocket shaft.

Runout

Soon after the inception of the TC96, there was a report from a respected performance engine builder that he found runout on the pinion shaft of a full nine-thousandths of an inch (.009"). At Heavy Duty, we have found lots with .003" or .004" runout, which are more than one or two-thousandths of an inch (.001" to .002") too much. This is the point where parts wear begins to affect the engine's longevity. Runout refers to flywheel truing specifications:

- Each integral flywheel shaft is machined at a perfect 90-degree to its flywheel face.
- Truing one flywheel to the other follows after pressing the crank pin into each flywheel crank pin hole; anything more than .003" runout of the shafts or flywheel rims will begin to produce excess engine vibration. This will lead to premature wear of all affected parts including support bearings and especially the life-blood oil pump.

- Excess pinion shaft runout will vibrationally affect the main pinion support bearing. Furthermore, the pinion bushing in the cam support plate will suffer as it will ream out. This will have negative effects on bottom end oil feed pressure since oil feeds through the pinion bushing into the pinion shaft and onto the bottom end crank pin and bearings. We check every Twin Cam that we take apart now with a micrometer dial indicator on the pinion shaft end to monitor this. Of course, there will be readily observable oil pump inside wear, if there is a problem with runout. If disassembling an oil pump and wear is evident always, check pinion shaft runout first for the possible cause.

Connecting Rods

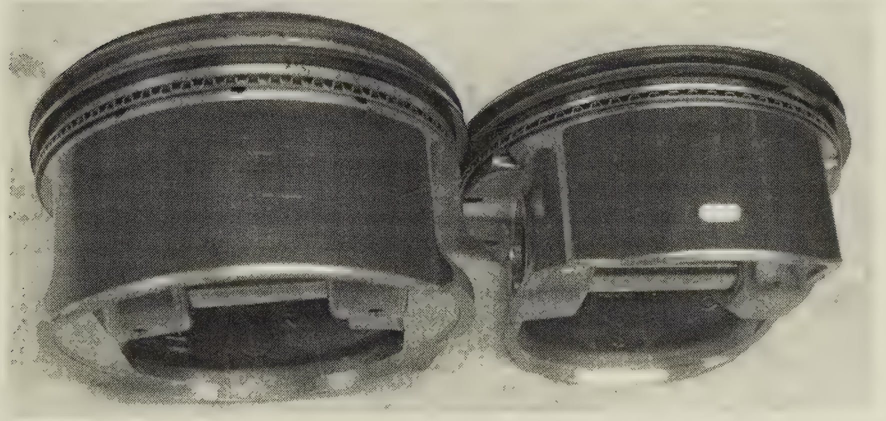
To help reduce the longer-stroke, larger-displacement engine's vibration, the engineers reduced the flywheel assembly's reciprocating weight by designing new connecting rods and pistons.

They are lightened, in ways that according to the engineers do not reduce their strength. After inspecting the connecting rod small ends that connect to the piston wrist pins and pistons, I have to take issue with the above statement. The con rod small ends taper from bottom to top on the 2007-to-present models, taking away much material away when compared to the squared full size 1999-2006 connecting rod small ends. They may be strong enough but cannot be as strong as what they have replaced.

The flip side is that any drop in the internal weight of reciprocating parts will allow for higher revving and less stress.

A running change in late-2010 and early 2011 Twin Cam engines replaces the connecting rod small end wrist pin insert-bushings to parent material bearings. Furthermore:

1. The upper taper of the connecting rod small end is now forged as opposed to being machined after casting. This is a cost savings measure as it eliminates a production step. The taper began utilization with the 2006 Dyna and all 2007-to-present Twin Cams to reduce reciprocating weight of the flywheels. This is an efficiency measure that reduces engine stress.
2. The parent material inner diameter (ID) dimension remains the same as with the precedent wrist pin bushing ID.
3. The parent material ID bore will now be honed to size. The installed wrist pin bushing required reaming (cutting) to size.
4. Replacement flywheel sets (crank) will use the parent material, wrist pin connecting rods. Therefore they will retrofit back to the 2006 Dyna Glide.



TC88 and TC96 Pistons: Thrust Face View

Pictured on the left is a 1999 to 2006 TC88 piston. On the right is the TC96 piston used in all 2007-to-present Twin Cams. The same hypereutectic piston is used front and rear. A directional arrow on the crown instructs even the most inattentive mechanic to point the piston to the front in the cylinder. The wrist pin hole is offset slightly. An Evo wrist pin is .792" thick while the TC88 one is .927" in diameter. Piston cooling jets squirt oil to the undersides to remove 50^0 F heat from the piston crowns. This combined with the black Teflon coating on the pistons from the oil ring down helps ensure correct break in and engine longevity. The term hypereutectic describes a piston manufacturing technique. It refers to the amount of silicon used in the cast piston alloy. They have the smallest expansion rates of any of the piston types allowing for the very close fitment to cylinder wall as seen with the Twin Cams. They are the strongest cast pistons, most resistant to piston-to-wall scuffing, and least likely to suffer a seizure situation. The 2007-to-present TC96 Twin Cam A and B models have their stroke increased ⅜" from the 1999 to 2006, 4.000" stroke to 4 ⅜" (4.375") stroke to achieve their displacement of 96 cubic inches. The Twin Cam 96 has the same stock bore of 3 ¾" as the TC88. Therefore, the TC96 can be increased to 103 cubic inches simply by safely increasing the bore to 3 ⅞" with exactly the same procedure as when the TC88 is bored out to 95 cubic inches. Surely, a more reliable engine would have resulted by using a bigger bore than an increased stroke although the stroke increase is a safe one as far as strokers go. With a longer stroke, piston speed increases, which lessens engine longevity because the piston must move further up and down its cylinder but in the same time, which generates more heat. Each piston's greater travel (swept volume) is responsible for four more cubic inches into the same size combustion chamber used since 1999. Thus the compression ratio increases to 9.2:1 on the TC96 from 8.8:1 on the TC88.

Reciprocating & Rotating Engine Flywheel Components

Balancing reduces vibration. Engine crank balancing involves the weight of two groupings of parts; reciprocating and rotating.

1. Reciprocating weight refers to the weight of all the flywheel parts that go up and down the cylinders like the connecting rods including the pistons, wrist pins, clips, and rings.
2. The other component in engine crank balancing is the rotating weight. These parts do not go back and forth but spin or rotate like the flywheels, shafts, and crank pin.

TC96 Piston Design

The piston design is like many stroker pistons.

The wrist pin bores are closer to the oil ring lands, which results in a shorter piston and 10% less weight, for a 6-percent total reduction in the flywheel assembly's reciprocating weight.

1. The piston wrist pins are also shorter than their TC88 counterparts are and therefore lighter. As with any piston, the wrist pins are in the middle of the piston but in line-parallel with the piston, front and rear thrust faces.
2. The thrust faces are round to match the round cylinder that they move against separated by a film of oil. The areas between the TC96 thrust faces under the ring lands are flat. They move inwards much further than their TC88 counterparts since there is no contact with the cylinder bore resulting in a lighter piston in the quest for less reciprocating weight.
3. The inward move of the piston sides results in less thrust surface area on the TC96 piston, which will lead to increased wear. It also decreases power-robbing friction.

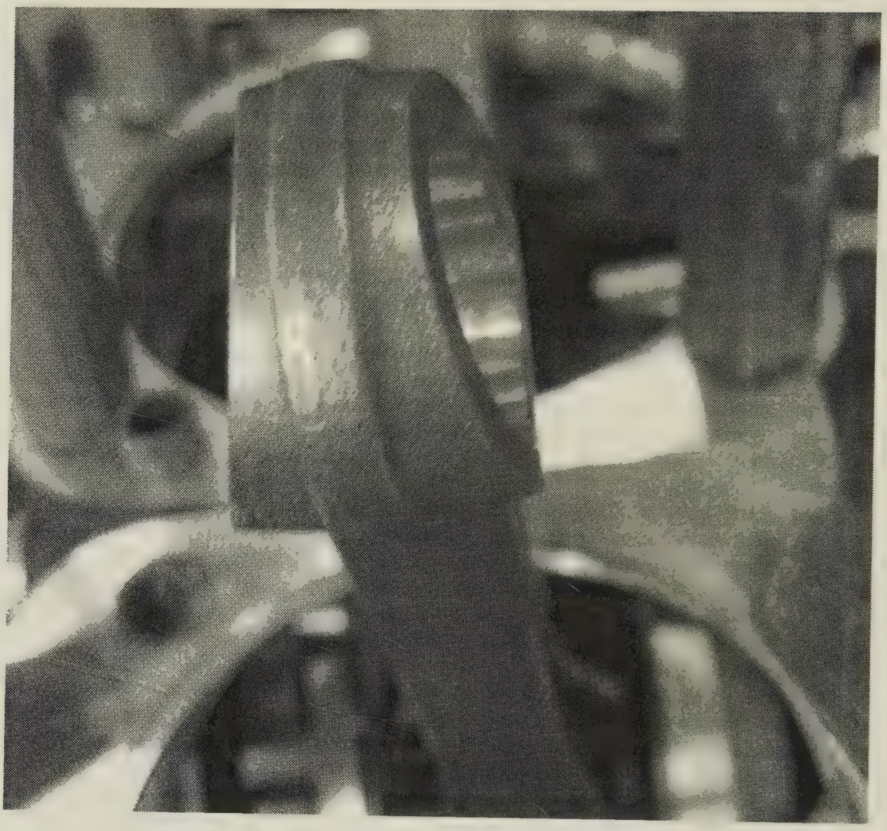
No modern H-D Big Twin and XL pistons that have gone before, contact the cylinder bore on the non-thrust faces. The earlier pistons have an elliptical shape that the reader probably would not notice unless looking for it. The front and rear thrust faces are rounded but the sides move in slightly.

1. Inside these two opposing flats are the piston or wrist pin bosses, a built up area of support metal for the wrist pin to fit through. The wrist pin fits through one piston boss, then goes through the wrist pin bushing located in the small end of the connecting rod and finally out into the other piston boss.
2. Circlips, fitting into grooves cut inside the outer piston pin bosses hold the wrist pin in place. The pin must float in the wrist pin bushing, again separated by a film of oil.

The pistons change direction slightly as they go up and down the 45-degree opposed cylinders so they need to be able to rotate slightly on the con rod bushing. The piston wrist pins and therefore the pistons themselves float in the wrist pin bushing. However, the wrist pins fit into the piston bosses with a light hand press at room temperature.

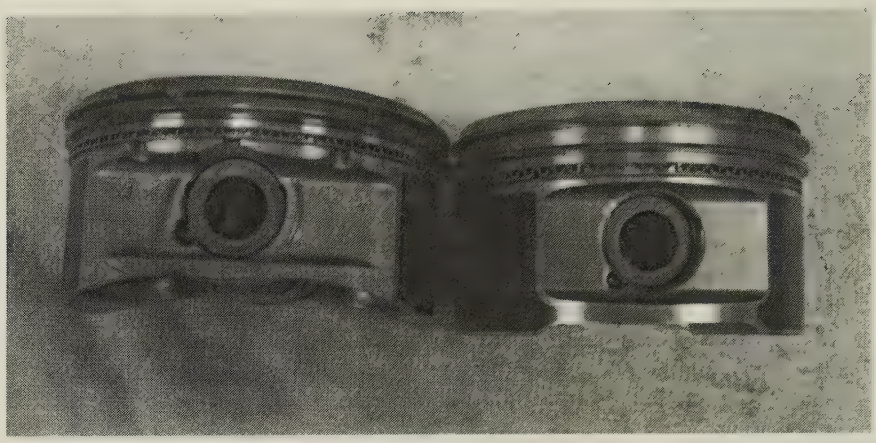
The less mass or reciprocating weight that moves up and down the cylinder not only reduces internal horsepower losses but also relieves stress. Imagine a piston barreling up the cylinder when suddenly in an instant it must stop and change direction. The same thing happens at the bottom of the cylinder. This racing, stopping, changing direction, racing, stopping, and changing direction occurs thousands of times a minute (rpm). Amplified piston speed occurs with an increased stroke, since the piston must travel further but do so in the same time-period.

1. The advantage of the stroker is more power. The TC96 has lots more torque.
2. The disadvantage is the increased piston speed with a shorter piston and the extra heat generated.
3. Offsetting but not negating the disadvantage is the lighter piston, wrist pin, and connecting rod small end and thus the resultant reciprocating weight reduction.



TC96 Connecting Rod: Wrist Pin Small End

Pictured is a TC96 connecting rod small end. Small ends refer to the smaller ends of connecting rods that house the piston wrist pin bushing. Big ends refer to the much larger opposite ends of the connecting rods that house the crank pin and bottom end bearing rollers plus roller cages. TC88 connecting rod small ends in use from 1999 to 2006 are much larger than the new TC96 ones. They are roughly square with the wrist pin bushing being the same length all around instead of tapering. Obviously, the TC88 con rod small ends are much stronger than the new tapered TC96 ones. Harley has made this change in order to decrease weight in order to reduce the crankshaft assembly reciprocating weight. Reciprocating parts like the connecting rods and their attached pistons travel up and down. Less weight means less stress especially when these parts must suddenly stop at the top (TDC), and the bottom (BDC), and then start moving again the opposite way. Lessening reciprocating weight was necessary to counter the extra stresses imposed by increasing the TC96 stroke to 4.375" from the TC88 stroke of 4.000". The shorter pistons must travel up further in their bore and back down further again but must do it in the same time; therefore, the pistons and connecting rods must do it faster. Beginning in 2011, the upper taper of the connecting rod small end is now forged as opposed to being machined after casting. This is a cost savings measure as it eliminates a production step. However, the big news is that the wrist pin bushing eliminates in favor of parent material. The inner diameter (ID) dimension remains the same as with the precedent wrist pin bushing ID. The parent material ID bore will now be honed to size. The installed wrist pin bushing required reaming (cutting) to size. Replacement flywheel sets (crank) will use the parent material, wrist pin connecting rods. Therefore they will retrofit back to the 2006 Dyna Glide.



TC96 and TC88 Pistons: Side View

Pictured is a 2007-to-present TC96 piston side view, compared to the longer-skirted 1999 to 2006 TC88 piston. The TC96 piston is necessarily shorter by almost three-eighths of an inch because the stroke increases by three-eighths of an inch. If not shorter, the piston crown, which is the top portion of the piston, would collide with the head at the top of the stroke (TDC), and the piston skirt would do the same with the flywheels at the bottom of the stroke (BDC). I say almost ⅜" shorter because the compression bumps up by bringing the piston crown a little closer to the combustion chamber. To combat the extra stresses of a stroke increase the piston along with the small end of the connecting rod is lighter. The TC96 wrist pin bores are closer to the oil ring lands, which results in a shorter piston at the top while the piston skirt length also decreases for BDC clearancing. Pistons are not round. The only rounded areas on a piston are at the front and rear when sitting in the cylinder bore. These are the thrust faces, which ride the cylinder, bore up and down. The sides of the pistons (shown) never touch the cylinder bores. The TC96 wrist pins are shorter in length and therefore lighter. This reflects in less material on the piston sides. Note there is also less thrust surface area on the TC96 piston, which will lead to increased wear. It also decreases power-robbing friction. The piston wrist pin bosses inside the TC96 piston have less support material also. These changes that remove structural strength account for 10% less weight. This translates into a 6% total reduction in the flywheel assembly's reciprocating weight, which helps offset the stresses of the stroke increase as well as the reduction in thrust surface area. I am against making components weaker by removing material but if anything, many TC88 parts are over engineered and immensely strong.

The Top End: The Heads and the Valve Train

Twin Cam heads have always been an impediment to more power. The TC88 heads flow less than 80c.i Evolution heads even though they service an extra eight cubic inches. This situation exacerbates when the TC88 is bored out to 95 cubic inches.

Engine efficiency with the added benefit of a performance boost is all about the delivery of air. Gas cannot burn unless turbulently mixed in the correct proportions with air. The TC88 head effectively turbulates the air. The flattop piston rising up against the smaller bathtub shaped combustion chamber surrounded by a squish band is the best design ever used on a Harley-Davidson. The problem is not their efficiency but the lack of sufficient air volume delivered.

Lack of sufficient air for an engine's swept volume capacity means an engine is not performing at its optimum power. This is why porting and polishing heads on the 1999 to 2006 engines is so crucial to more power since we need to increase air intake.

- The bad news is that the TC96 head base on much the same casting as the Twin Cam 88's!
- The good news is that the TC96 heads have been factory massaged.

I highly recommend porting and polishing on the TC96 heads also. Even though the TC96 head has better flow than a TC88 head, it must service an additional eight cubic inches.

Lighter Valve Train: 2005 to Present

Valves and guides are thin stem since 2005. This was an important advance since the valves are lighter.

- Traditionally Harley-Davidson Big Twin valves have a ⅜" diameter valve stem.
- This diameter now reduces to $^{5}/_{16}$".

Valve trains in pushrod-operated engines like all modern traditional Harley's, are heavy affairs to move up and down with speed (rpm). The weight limits rpm capabilities.

Overhead cams (OHC) like those used in the V-Rod actuate the valves directly and are capable of high rpm's. Any time the valve train lightens, the engine will be capable of slightly higher rpm's and therefore more power. There is the added advantage of increased parts longevity.

Furthermore, a lighter valve train requires less valve-spring seat-pressure. Seat pressure does not need to be as great to return the valves to their seats as the commanding valve lobe rotates to a lower position. This relieves stress on the valve train increasing parts longevity.

TC88 and TC96 Valve Seats

One of the principle areas addressed when porting TC88 heads is a severe overhang of the valve seat relative to the head port. Valve seats press fit into the alloy heads. A very hard steel alloy is required to withstand returning *slam* from the valves.

For an optimal flow of air, the valve seat should radius and blend into the port it serves. Valve seat matching to the head ports is improved on the 2007-to-present models relative to the 1999 to 2006 Twin Cams. However, there is regrettably still some overhang requiring contouring. This cannot be over-emphasized, as most flow improvement in any porting and polishing operation occurs within one-half inch of the seat area.

Engine/Electronic Parts Comparison 2005, 2006 Dyna and 2007 Big Twins

Part Description	06 Dyna	TC96	5-speeds
Flywheel Assembly	23955-06	23729-07	23957-99D
Head	17106-06 f 17112-06 r	17178-06 f 17179-06 r	17178-06 f 17179-06 r
Valve guide	16465-06	Same	Different
Intake valve	18074-05	Same	Different
Exhaust valve	18085-05	Same	Different
Valve seal	18094-02	18094-02A	18094-02
Cylinder	16525-99	17458-07	16525-99
Piston stroke (2006 4”; 2007 4 ⅜”)	21936-99	21949-07	21936-99
Crankcase	24654-06	24621-06A	24596-99C
Cam bearing	9215	Same	Different
Gasket kit cam service	17045-99C	Same	Same
Bushing crank (support plate-pinion)	25241-99	Same	Different
Cam support plate	25355-06	Same	2526799B
Cam cover	25369-01A	Same	Same
Camshaft chain & fastener kit	25585-06	Same	Different
Camshaft kit (2)	25595-06	24608-07f 25590-07r	Different
Cam Sprocket: 17 teeth all years	25673-06	Same	25609-99
Chain primary cam drive	25675--06	Same	25610-99
Chain secondary cam drive	25683-06	Same	25607-99
Sprocket cam drive-34T	25728-06	Same	25716-02
Spacer(s) (.100”.150” in .010”steps)	25729-06	Same	Different
Oil pump assembly	26037-06	Same	26035-99B
Chain tensioner primary cam drive	39968-06	Same	39954-99A
Chain tensioner secondary cam drive	39969-06	Same	39964-99A
Induction module assembly (EFI)	27600-06	27708-06	Different
Injector (25^0 versus 8^0)	27625-06	27709-06A	Different
Rotor assembly	40356-06	40356-07	Different
Stator	30017-01A	29987-06A 3phase50amp	Different
Voltage regulator	74631-06	74505-06	Different
Electronic control module base level	32534-05A	32534-05B	32622-04B

Heads and component parts coordinate for a lighter valve train plus higher flow. Pistons are shorter to accommodate the ⅜"-increased stroke. Bore is the same (3 ¾"). TC96 big bore from 3 ¾" to 3 ⅞" will increase displacement to 103 cubic inches. Stock barrels may be bored out very safely. Cam support plate uses parent material instead of traditional bearings for outboard cam journal support. Camshafts are 5-piece so appropriate metals and hardening can be used for journal ends and the separate cam lobes. Rear journal size increases to 1.000" from .875" utilizing wider diameter, higher load inboard bearings. The oil pump has 10% more flow, and 23% more scavenging (return), which will help alleviate venting or blowby. Timing chains are now roller with rounded sides; tensioners are hydraulic instead of spring loaded with a new nylon pad. Fuel injectors are at more desirable angle of 25^0 versus 8^0. The alternator rotor and the compensator shock absorber are now one piece.

Anti-Reversion

Removal of the anti-reversion step at the outside of the TC96 exhaust port opens up the port considerably allowing much more flow.

The TC88 exhaust port anti-reversion step was an improved design change in 1999 with the advent of the Twin Cam even though it restricted the all important exhaust flow properties of the head design.

- Anti-reversion is also extremely important as it helps prevent exiting exhaust gases from returning and soiling the fresh intake charge in the combustion chamber.

As exhaust-pulses expel through the exhaust valve, out the port and into the header system to the mufflers, Kinetic wave exhaust-gas pulses will return up the pipe many times before finally leaving the muffler. It is of utmost importance that these bastardizing pulses of burned gases bounce off a closed exhaust valve. These reversion gases also bounce back off anti reversion steps built into the heads. Installation of anti-reversion torque cones in the exhaust header pipes where they meet the exhaust port on the 2007-to-present models is easily done and inexpensive.

The oft-ignored exhaust system is complex as only one of its functions is to control the timing of these power-robbing pulses.

Improved TC96 Head Flow

Another improvement to the reworked TC96 head castings is that a restrictive-to-flow curvature on the inside of the turning exhaust port has been eliminated with the over sizing of the whole port. It still radiuses narrower to the valve seat. This narrowing down will increase flow as explained by Bernoulli's Principle.

The exhaust valve (18085-05) is also more conducive to improved flow as it approaches a tapered tulip shape where the stem joins the top of the valve as opposed to the 1999 to 2005 more abrupt flatter shaped exhaust valve top.

I measured some 1999 to 2006 TC88 exhaust head ports and compared them to TC96 ports and found an average approximate diameter increase of about .175".

1. Intake ports are pretty much the same size but a noticeable and superior difference is that the seat edges and casting they fit into mate correctly on the heads. The improved intake port shape over previous Twin Cams allows for enhanced intake air flow.
2. The port curvature is gentler and not as abrupt when changing course allowing smoother flow.
3. The intake valve's (18074-05), head is also approaching a higher flow tulip shape.

4. The valve guide (16465-06) has a shorter reach into the head, which is less obstructive to increased flow.
5. Another obvious improvement is better angling of the intake manifold flanges (26993-06) and the manifold aperture relative to the port it serves. The same flange serves both heads. In keeping with this, the actual flange mounting holes in the head itself are now equidistant from each other as well as the port-center. Earlier heads use front and rear flanges (27009-86A and 27010-86A) that mount to holes in the head that are offset and not equidistant.
6. This combines with the new EFI injector angle of 25° from the previous 8° injector serves to help increase flow of air and fuel delivery.
7. The valve seal improves once again from the 2002 change, which was also superior to what went before. The seal incorporates into the lower valve collar since the 2002 change but it now incorporates an improved more pliant rubber-like material that will hopefully have a longer service life. The new seal (18094-02A) is orange in color while the 2002 to 2006 one is black rubber (18094-02).

The heads still require porting and polishing to raise the horsepower, which has not increased substantially from the TC88 to the TC96 even with eight more cubic inches and higher compression. Nevertheless, the head is an improvement over what went before.

A major Twin Cam engine deficiency has always been insufficient head air flow. The head design is the best since 1903. Quality is excellent. It is just that the ports and valves do not deliver enough air to allow the engine to be what it could be. H-D has addressed air flow to some extent in the TC96 but not enough.

Twin Cam Boondoggles

The successful to date timing chest changes experimented with in the 2006 Dyna Glides incorporate into the 2007-to-present TC96. The three boondoggles to the Twin Cam engine have always been:

Insufficient head air flow. Porting and polishing improves head flow to help meet the combustion needs of the engine.

1. Problematic timing chest mechanical deficiencies. Hopefully the new design will prove itself over time.
2. Emissions controls. Emissions controls are difficult to deal with on a two cylinder, old technology pushrod operated engine. Six and eight cylinder cars utilize the symbiotic attributes that more cylinders provide each other to overcome the high air to gas ratios and restrictive ignition timing curves necessitated by EPA dictates. This combines with superior technologies of overhead cams; multi-valve redesign heads, liquid cooling, and sophisticated fuel delivery give the automotive industry advantages that Harley-Davidson nostalgia may not be able to take advantage of for marketing reasons.
3. However, newer technologies can incorporate EPA dictates, reducing pollution, improve gas mileage, and create higher levels of performance. Many thought this impossible but one only has to look at the new generations H-D Delphi electronic fuel injection and the sophistication of engine-management system computerization to see a current working example attempting to meet current deficiencies.

Harley-Davidson is really getting up to speed within the restrictive parameters it must work. This will not be enough for the future, as compromising traditionalism will be necessary.

The insider rumor mill was whispering that there will be optional Bagger models fitted with water-cooled V-Rod engines in 2009. It did not happen in 2009, perhaps due to the Great Recession beginning in 2007 but make no mistake, it is coming. However, there are two problems with this.

1. First, the V-Rod mill is too fast on the top-end for the fiberglass air dynamics on the Baggers. Speed wobbles will be a concern unless fiberglass aerodynamic redesign occurs.
2. Secondly, the V-Rod is not torquey enough in the bottom end to launch a big Bagger. This will resolve with heavier flywheels or perhaps gear ratio reduction changes.

Where will the Radiator go when the Future becomes the Present?

Where are they going to put the radiator? In your face big and bulky out front; sleek and contoured with custom sides to blend it in, or perhaps hidden and incorporated into body design. Willie G. patented a radiator design over 3-decades ago for the ill-fated Nova. The radiator hid under the seat with air scoops feeding the cooling air and negative pressure drawing this air through the finned rows.

New Improved Timing Chest?

Harley-Davidson attempts to address 1999 to 2006 timing chain problems with a new system using the 2006 Dyna Glide as a test ground.

The *silent* cam chains replace with a roller chain.

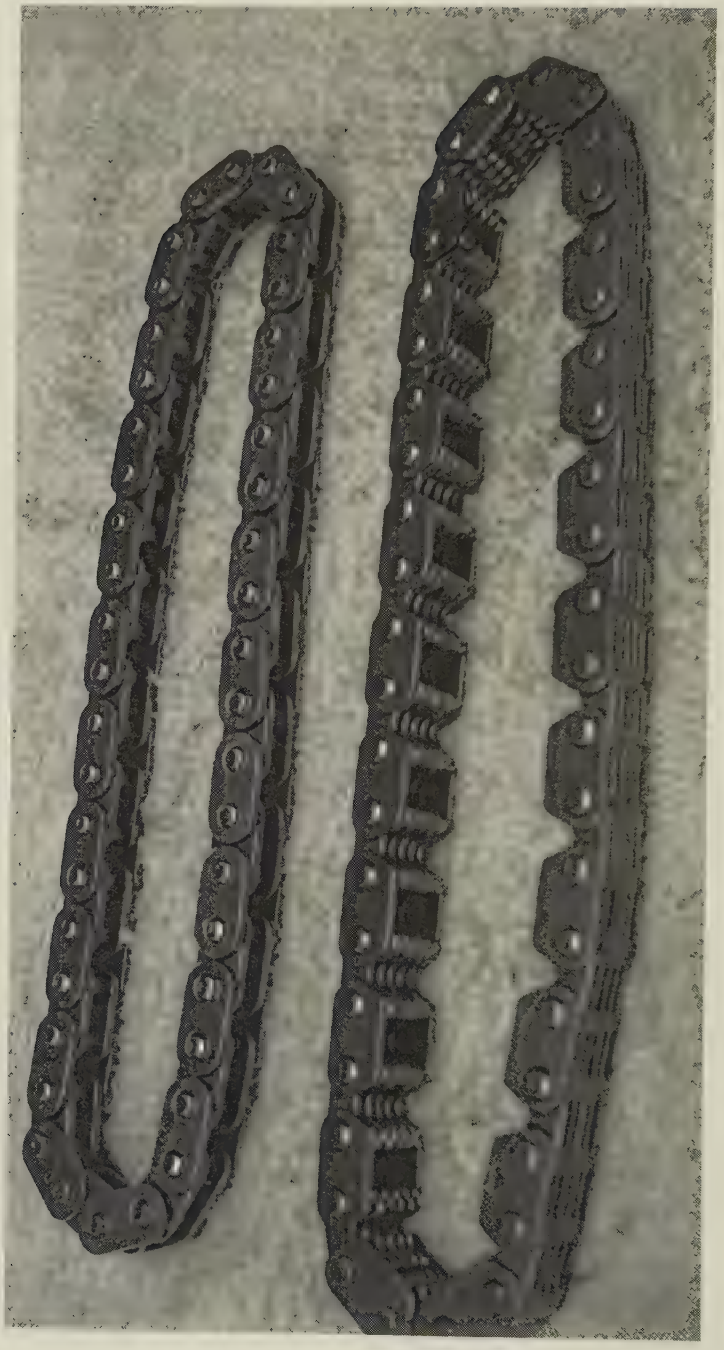
1. The cam support plate eliminates traditional outboard cam bearings in favor of parent material bearings.
2. Hydraulic cam chain tensioners replace the spring-loaded adjusters.
3. Nylon has replaced the previous shoe tensioner material.
4. Lastly there are increased load capacity inboard cam bearings in the engine casing.

The earlier timing chest mechanism has been retained by all the 2006 Softail and touring Big Twins. However, the modifications carry over into all the 2007-to-present Twin Cams including the CVO 110 and the TC103.. Some changes seem to be very much better and will eliminate many of the problems in the past.

The new roller chains do not have sharp edges like the 1999 to 2006 silent cam chains. Reportedly, GM Northstar engines and all Polaris Freedom motors use the same type roller chains. Cam drive chain failure on these engines has not been an issue as of 2011.

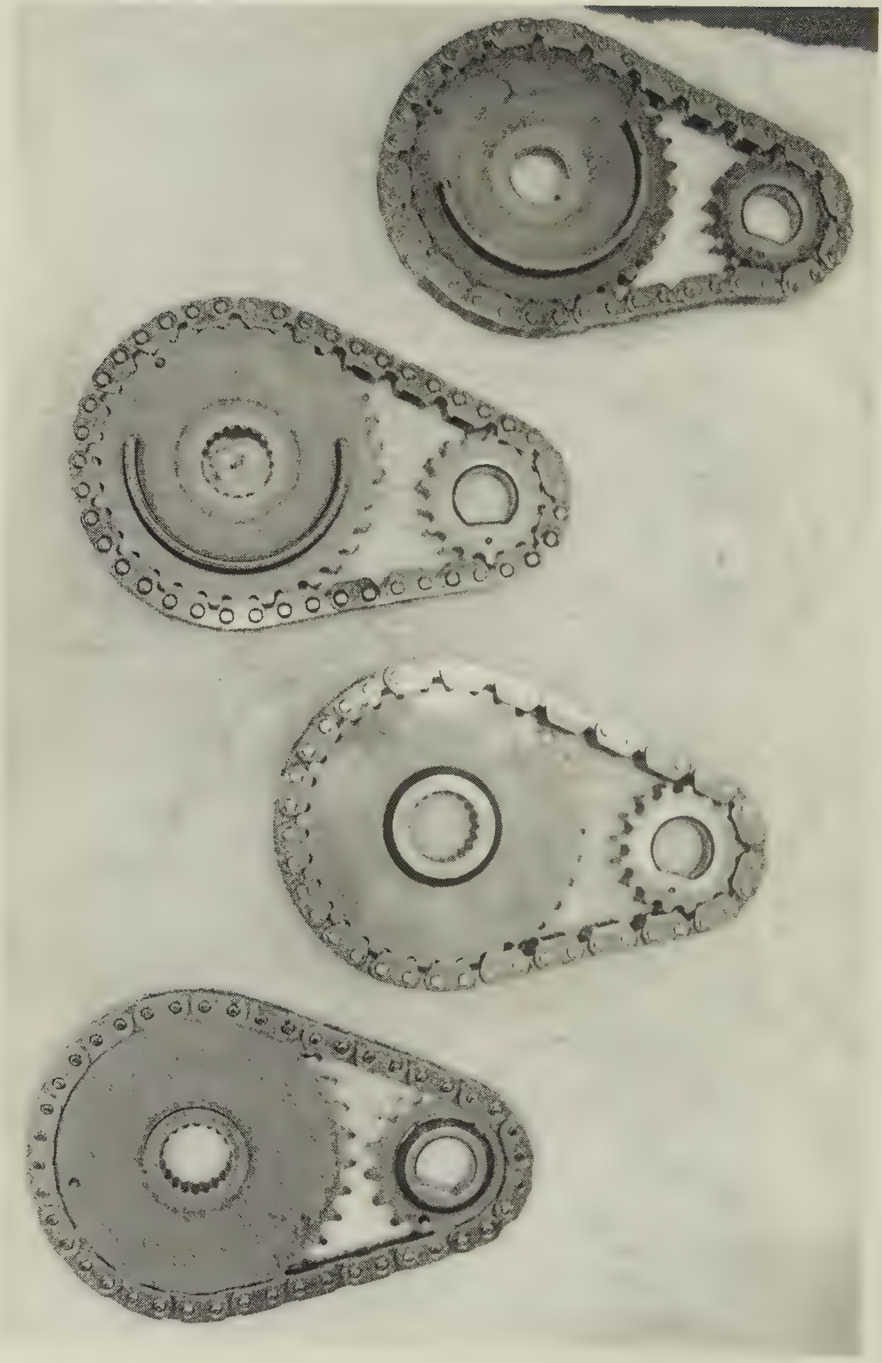
The hydraulic units work much the same as a hydraulic lifter with a small spring inside to help tension while the hydraulic pumps up. A consistent amount of tension is produced very similar to the hydraulic tensioners that have successfully monitored chain slack to the counter balance chains in the Twin Cam B models since 2000.

Engineers are finally beginning to admit that the 1999 to 2006 tensioners often suffer excessive wear.



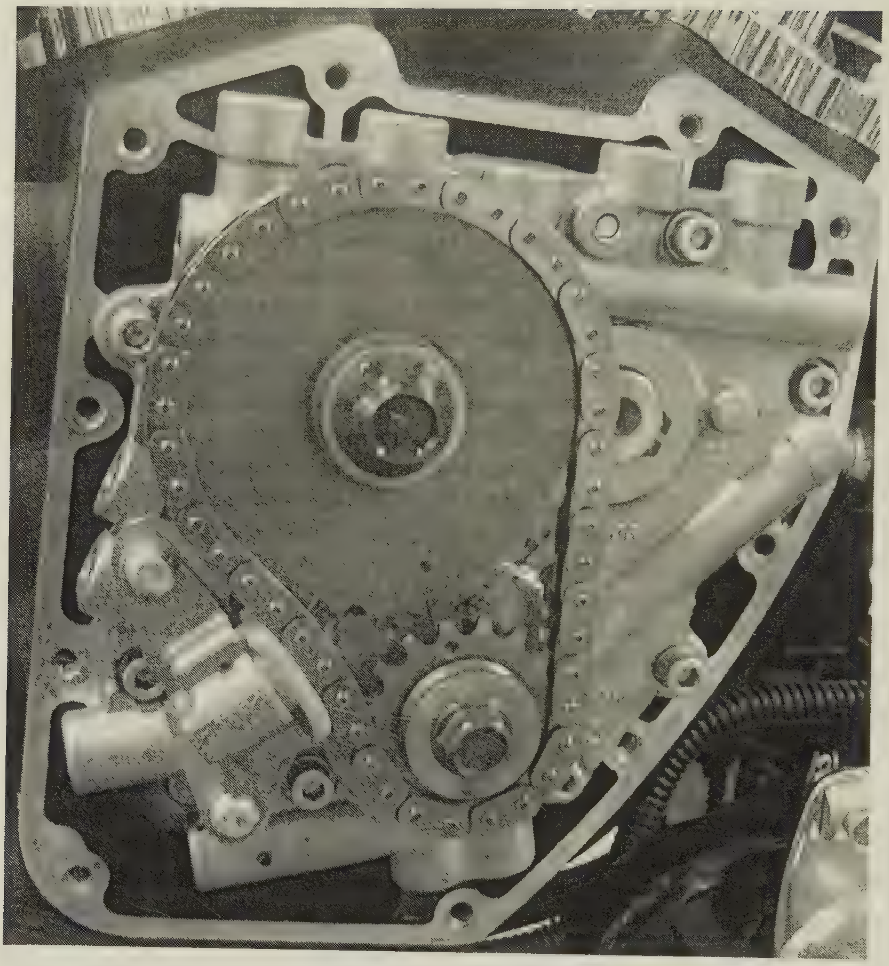
Comparing TC88 and TC96 Twin Cam Timing Chains

The 2006 Dyna and all 2007-to-present Twin Cam shorter *inboard* cam-support-plate secondary cam-chain (25683-06) is pictured on the left. To the right is the 1999-2006 (except the 2006 Dyna) *outboard* cam-support-plate primary silent-cam-chain (25610-99). Secondary cam chains are shorter than their primary counterparts. Upon comparative examination, the differences are clear. Engineers felt the early system would last the life of the engine without servicing. We find the TC88 chain adjustor pads badly worn, many times with only a few thousands of miles on the bike. I feel that the combination of three factors contributes to rapid wear of the tensioner pads from 1999 to 2006. Sharp abrupt plate edges on the early silent chain combine with a "bouncing" spring-loaded chain tensioner with problematic tensioner pad material. These factors join to create uncertainty when deterioration of the adjuster pad would occur. There is no noise indicator when this happens. Examination of the oil filter pleats will tell that it is already in progress. The 2006 TC88 Dyna and 2007-to-present TC96, TC103 and CVO 110 timing roller chain has less abrupt edging, less contact with an improved nylon pad, and is firmly and consistently tensioned by a hydraulic adjuster. Time will tell how efficient this new system becomes. As of this writing in 2011, there have been no widespread problems.



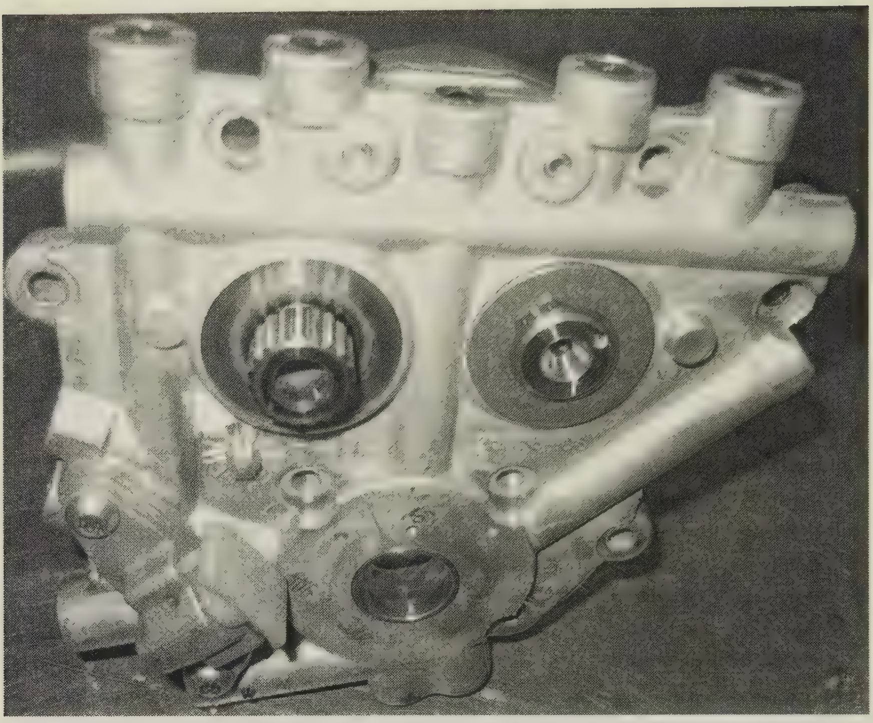
Twin Cam Timing Chest Cam-Drive Sprockets
Comparison 1999-to-Present

Pictured is the sequential order of 1999-to-present Twin Cam timing chain drive sprockets. The top set includes the 1999 to early-2000 rear cam sprocket with the problematic cast in keyway. If this methodology is used, the keyway should be a separate key as the stock cast-in one has a habit of shearing. If the keyway shears, the larger 34-tooth rear cam drive gear will rotate at will on the rear cam journal end. Thus, engine ignition spark timing will be adversely affected thereby preventing the engine from running. All sprockets and the cams they ultimately drive mechanically-time to each other relative to flywheel and piston location. Notice the slot on the 17-tooth pinion drive gear that will align on a mating pinion shaft slot. Some timing marks are also visible in the picture on the sprockets themselves for correct assembly alignment. This allows the ECM computer to time the spark at the correct time because all moving parts of consequence inside the Twin Cam engine mechanically-time to each other. Therefore, the ECM knows where every moving part is in relation to other moving parts. Notice the sharp, serrated edges of the silent cam drive chain on the top three examples. The half circle ridge on the 34-tooth rear cam-drive sprocket is part of the Hall effect timing system. The cam position sensor, which is a magnet that reads this ridge start and end, sends pulses (information), back to the electronic control module (ECM), to determine when to spark the plug. Second from the top are late 2000 to circa 2001 rear-cam-drive sprockets. A female spline center corrects the keyway-shearing problem. The rear cam end journal has a similar mating male spline appendage. The Hall effect cam sensor ridge remains. Third from the top is circa 2002 to 2006 (except 2006 Dyna) assembly where the change is the elimination of the cam sensor and rear-cam-drive-gear Hall Effect ridge. The ECM now relies solely on the crankshaft sensor to read the notched left flywheel to determine piston location and *speed* for timing spark firing. Bottom is the 2006 Dyna and all 2007-to-present Twin Cam drive sprockets and timing chain. The big change is the new roller timing chain, not the silent variety used on the three previous setups. I hope this new chain design will not wear the adjuster pad. It is late-2010 as I write and so far, so good. The 2006 Dyna and 2007-to-present Twin Cam sprockets are also thinner than the 1999 to 2006 sprockets. For an explanation of Hall effect please see sections; *V-Fire II Ignition Hall effect Trigger Rotor* and *V-Fire III Ignition Hall effect Trigger Rotor* in Chapter IX, *Synchronizing Ignitions and Fuel Delivery.* Hall effect devices have been in use since their discovery in 1879 to also fulfill a variety of necessary functions in Twin Cam motorcycles such as the fly-by-wire throttle grip sensors.



2007-to-Present Twin Cam Outboard Cam-Support-Plate Timing Sprocket Assembly

Pictured are the 2006 Dyna and all 2007-to-present Twin Cam timing sprocket assembly as it fits onto the outboard side of the cam-support-plate (25355-06). The primary drive chain (25675-06) is a roller chain with rounded edges. It adjusts constantly and automatically via the nylon hydraulically operated pad (39968-06). The previous sharp-edged 1999 to 2006 silent chains (25610-99 primary, 25607-99 secondary) prematurely wore the spring-loaded adjuster pad (39954-99A primary, 39964-99A secondary). The smaller 17-tooth crankshaft cam drive sprocket (25673-06), sits on the end of the rotating flywheel pinion shaft that extends into the timing chest and through a bushing in the cam support plate. It is held by a threaded-in bolt and precision ground washer (25566-06)). The 34-tooth cam drive sprocket (25728-06) is internally splined and fits over a mating male spline on the end of the rear cam outboard journal. It is also held by a bolt and washer (25278-06). The sprockets are thinner than previous ones. The rear cam outboard journal sits in the parent material bearing of the cam support plate (not visible). The primary timing chain connects the two sprockets so the pinion drive sprocket will turn the rear cam sprocket and thereby rotate the rear cam. Notice the alignment of both sprocket-timing marks; all internal moving engine parts time to each other. The secondary cam drive chain (25683-06) behind the cam-support-plate connects the two cam sprockets (not visible). The rear cam driven by the primary sprockets drives the front cam via the connecting secondary cam chain Thus; the rear cam drives and rotates the front cam. A hydraulic adjuster and nylon pad also adjust this chain. The oil pump sits behind and bolts to the cam support plate on the pinion shaft.



Twin Cam 2007-to-Present Outboard Cam-Support-Plate

Pictured is the outboard side of the cam support plate (25355-06) for the 2006 Dyna TC88 and all 2007-to-2010 TC96, TC103, and CVO 110 models. The primary timing chain (25675-06) and its 17-tooth pinion drive sprocket (25673-06) and the 34-tooth rear cam-drive sprocket (25728-06) have been removed. The next picture *2007-to-Present Inboard Cam-Support-Plate: Cams Installed* will show the inboard side of this same cam support plate. The left side male-splined appendage is the end of the rear cam outboard journal. The 34-tooth rear cam-drive sprocket is also female-splined and fits over this appendage. The sprocket bolts with bolt kit (25566-06) onto the rear cam via a threaded hole in the end of the splined appendage. The front cam end outboard journal is visible to the right. The circlip (H-D 11461) holds the front cam in place. Between and below the two cam ends is the pinion shaft bushing (25344-99) in the cam-support-plate. The pinion shaft bushing eliminates after 2010 in favor of parent material. The slotted pinion drive sprocket fits onto the pinion shaft's slotted end that fits through this pinion shaft bushing. It affixes via a bolt kit (25566-06) threaded into the end of the pinion shaft. The raised tubular berms on the support plate give the reader a good idea of where internal oil passages locate. The cam-support-plate also functions as an oil distribution center for the whole engine. To the left of the pinion bushing (parent material beginning in 2011) is the primary timing chain nylon adjuster pad (39968-06) sitting in its hydraulic adjuster bolted to the outboard side of the cam support plate.

TC96 Softail Counterbalancer Servicing

The Twin Cam 96B engine balancers have a new one-piece balancer support bracket (14728-07). There are new bearing installer and removal tools required for servicing. The balancer bearing installer tool for Softail models (HD-48309) installs the new bearing and balancer for the TC96B engine. The new bearing presses onto the balancer before the assembly presses into the right side engine casing. Support the engine casing when pressing in the balancer assembly complete with the bearing to avoid problems. The outboard balancer bearing remover and installation tool (HD-48474) allows the mechanic to remove and install bearings into the chain-guide support plate.

Finally, there is one more tool required for working on the TC96B engine balancers. The balancer and bearing puller tool (HD-48457), looks like a typical puller with outboard support studs that extend from a flat extractor steel plate to the right side engine casing. An appendage puller extends down through the center of the plate that does the actual pulling via a threaded rod moved up by tightening a nut on the rod and against the support plate. Reverse the support plate for pulling front and rear balancers.

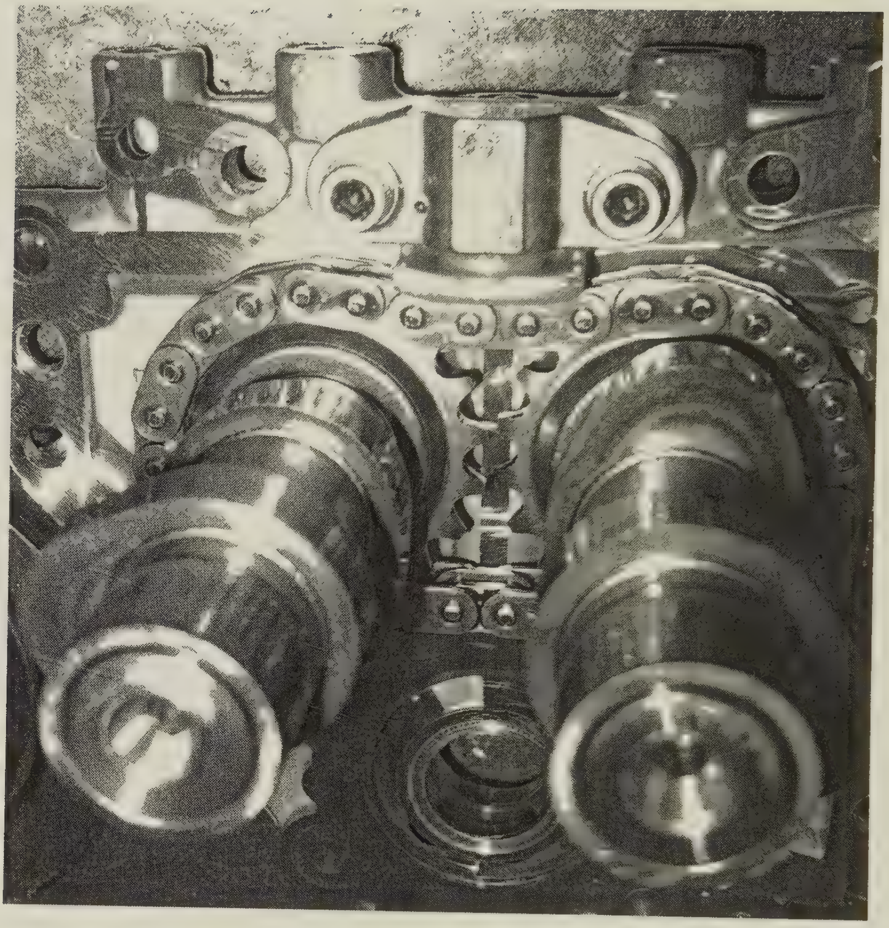
The Cam Support Plate

1. The new Twin Cams in 1999 and early 2000 had two *ball* bearings encased in the cam support plate for the outboard cam journal ends to rotate in. H-D used the rear ball bearing because it is quieter than a roller bearing. However, the rear cam ball bearing couldn't handle the stresses produced by the rotating rear cam assembly. The *roller* bearing is a natural replacement on the rear cam since it handles these stresses much better. The different tension and loads placed on the front cam are ideal for a ball bearing.
2. Late 2000 to 2006 Twin Cams used a ball bearing for the front cam and a roller bearing for the rear cam support.
3. The 2006 Dyna Glide and all 2007-to-present TC96, TC103, and CVO 110 Twin Cams eliminate traditional bearings in favor of parent material bearings that are bored holes in the parent material cam support plate.
4. This is an ongoing trend for modern Harley-Davidson's, and in my opinion has everything to do with planned obsolescence and cutting manufacturing costs. Before I explore this trend, further let's look at oil film strength; and where the logic of eliminating bearings may lie.

Oil Film Strength Protection

No internal engine part is ever supposed to have direct contact with mating parts as they move against each other. A film of oil always separates them, many times only molecules thick. One of the main functions of the lubricant is to maintain high film strength, which is the ability of oil to remain between and separate two parts such as a bearing surface and bearing under great pressure.

On a personal note after riding and working on Harley-Davidson's since 1968, I need to express a personal observation. H-D is a great company and really does try to make a wonderful product that we all love. Nonetheless, it seems that every time I see a good correction to a problem like the hydraulic tensioners and rounded edge roller chains, I see something that was working changed. I hope I am wrong about the longevity of these parent material-bearing supports.



2007-to-Present Inboard Cam-Support-Plate: Cams Installed

Pictured is the inboard side of the cam-support-plate (25355-06) for the 2006 Dyna TC88 and all 2007-to-present TC96, TC103, and CVO 110 models. The outboard side is shown in the previous picture. The shorter secondary timing chain (25683-06) connects the cam sprockets. The right side cam is the rear drive cam whose splined end affixes to the rear cam-drive sprocket on the outboard side of the plate (not shown). The rear (right), cam therefore drives the front (left) cam, via the timing chain and sprockets. This sounds backwards but it is because the cam support plate orients the cams correctly when flipped for installation in the timing compartment. Both the two outboard primary and the two inboard secondary chain cam sprockets are thinner than the 1999 to 2006 sprockets. The secondary timing chain adjusts consistently and firmly by the secondary hydraulic chain tensioner (39969-06) bolted to the inboard side of the cam support plate directly above and between the two cams. The cams are now 5-piece. TC88 cams are 1-piece. The cam lobes press onto the camshaft. The lobes and the camshaft journal ends are made from differing steel alloys. They are hardened specifically for the tasks they perform and the stresses they must cope with. The pinion shaft bushing (25344-99) is visible directly below and between the cams. The pinion shaft supports and drives the oil pump. The oil-pump centers and fits onto the pinion shaft. It bolts to the inboard side of the support plate below the cams around the pinion shaft bushing.

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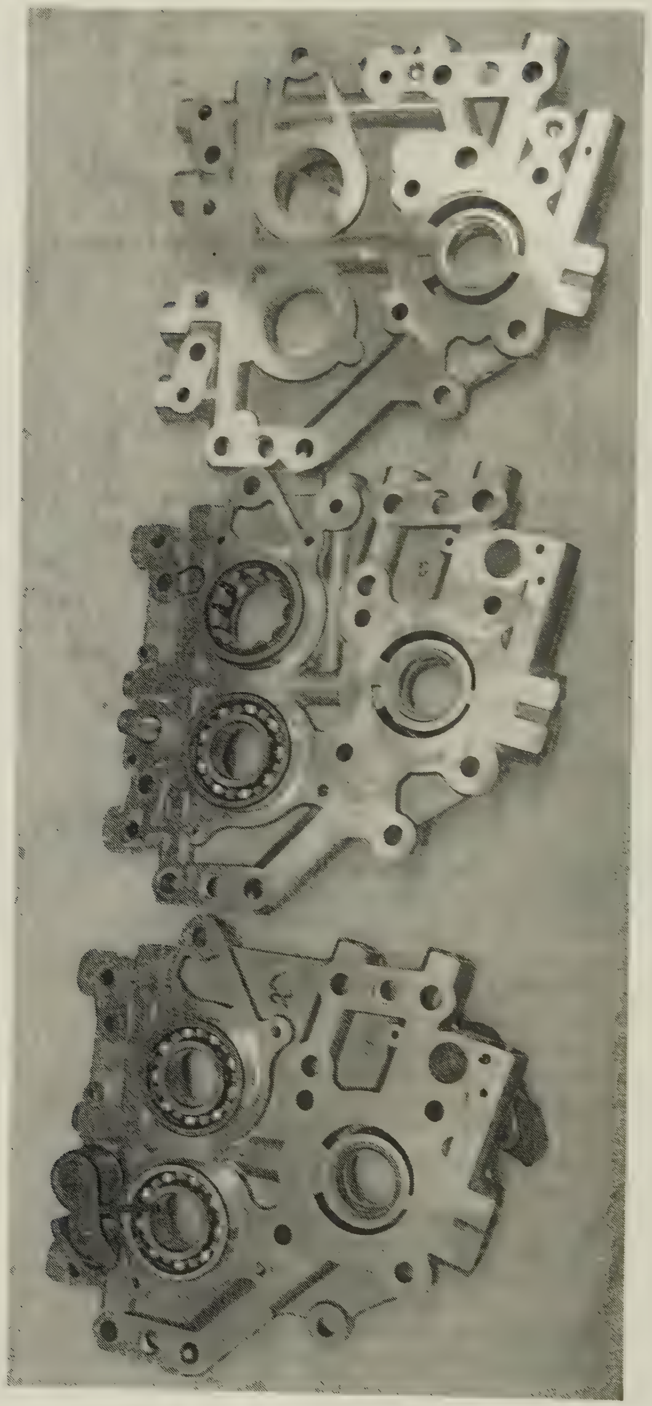
1. In fairness, the 1999-to-present connecting rods big-end-journals are also parent material with no problems arising. Of course, the hardened cast iron bearing moves around the crank pin. However, the cams move inside the aluminum parent material bearings in the support plate. Moment Arm Force is not a factor here.
2. My automotive gearhead friends inform me the automotive industry has used parent material bearings for decades.
3. If the cam sprockets located in the center of the H-D camshafts instead of one end, then the Moment Arm Force could not attempt to oblong the parent material bearing holes.

The previous roller and ball bearings also control end thrusting as the cams rotate under stress. We shall see if end-thrust-play will develop into a problem with the new Twin Cams. H-D now uses protective thrust washers (25729-06) between .100" and .150" thick; one for each cam sits on the outside of the cam support plate parent-material bearing holes for protective and endplay tolerance purposes. The 6-different thickness thrust washers are available in sizing increments of .010". A built-in thrust surface on the cam journal protects the inboard side.

As a further note, the parent material outboard cam journal holes were not deburred after machining, in the cam support plate that we took out of my bike! This is a standard practice after any machining process and shows carelessness and lack of quality control when it occurs. I hope that this is the exception and not the rule.



A Brief Pictorial Twin Cam History of Cam-Support-Plates

Pictured are the inboard sides of the various cam support plates 1999-to-present. The bushing in each plate to the right of the outboard cam journal bearings is the pinion shaft bushing (25344-99). Rotate the picture clockwise 90^0 to view the support plates as they align in the engine, whereby the pinion bushing sits below and between the cam journal bearings. The pinion shaft bushing supports the end of the pinion shaft as well as feeding oil into the shaft for delivery to the bottom end crank pin, bearings and connecting rod journals. The pinion shaft supports and drives the oil pump inner geroters. However, four bolts hold the oil pump body to the inboard side of the cam support plate located around the pinion bushing. The bottom pictured cam support plate (25267-99) is the problematic one used in the first Twin Cam engines in 1999 and early 2000. Ball bearings (H-D 8990) supported both cam-journals. The upper bearing is for the rear cam journal. Engine stress causes this ball bearing to rapidly deteriorate and many times destruct. Notice the spring-loaded secondary cam chain adjuster (39964-99), which is another cause of timing chest problems above the front-cam lower ball bearing. The middle cam support plate (25267-99B) began its usage in late 2000 to 2006 to correct the rear cam ball bearing failure. Supporting the rear cam journal is now a roller bearing (H-D 8983), which handles the stress easily. The top cam support plate (25355-06) used on the 2006 Dyna and all 2007-to-present Big Twins uses *parent material* instead of bearings. It's superior (hopefully) metallurgy relies on oil film strength to lubricate and separate the cam journal ends from the support-plate parent journal holes. The 2011-to-present cam support plate is not shown. It is the same as its predecessor except the pinion shaft bushing eliminates after 2010 in favor of parent material. The cost efficiency bean counters are saving the Motor Company money hopefully not at the expense of reduced parts longevity. Time will tell.

The Andrews Solution

Retrofitting 2007 Timing Components

John Andrews of Andrews Products, (www.andrewsproducts.com) who is always on top of his game has developed a kit combining with H-D parts to adapt the 2006 Dyna-2007 Big Twin-to-present roller chains to all older predecessor TC88 engines. Timing chain adjuster shoe wear reduces because:

1. The new roller chains have rounded edges.
2. The hydraulic adjusters also give more even and commanding support.
3. In addition, the Factory uses nylon to replace the old pad material.

The Andrews kit uses the late style 2006 Dyna-2007-to-present Harley-Davidson:

1. Cam support plate (25355-06).
2. The primary (25675-06) and secondary (25683-06) roller cam-drive-chains.

3. The hydraulic chain adjusters (39968-06, 39969-06).
4. The new improved oil pump (26037-06).
5. A 17-tooth thinner crankshaft cam drive sprocket (25673-06).
6. The 34-tooth thinner cam-drive-sprocket (25728-06).
7. The camshaft chain and fastener kit (25585-06).
8. Plus some other minor H-D parts.

Andrews has manufactured performance cams that will adapt the above parts to the earlier 1999 to 2006 Twin Cam engines. The 2006 Dyna and 2007-to-present new style Andrews cams for 1999 to 2006 fitment use the earlier camshaft inner bearing .875" journal size in order to fit into the earlier and smaller inboard engine case cam bearings (H-D 9198).

With the advent of the 2006 Dyna Glide, the inboard cam-bearing size increases to 1.000" and continues with all 2007 and later Twin Cams. This is one reason that the new style cams will not retrofit to earlier Twin Cams and vice versa. Another is that the cam chain sprockets are thinner.

Except for the camshafts, all of the above parts are stock Harley-Davidson. It is now possible to adapt the new roller chains to older TC88 motors and get away from the silent chain systems, which have been so prone to rapid wear and early failure.

It may also be possible to adapt a 1999-2006-cam support plate with bearings and a 2005 type oil pump (26035-99B). However, it will require manufacturing earlier camshafts with the later 1.000" inner bearing journals. Why would some riders want to do this? The reliable front ball bearing and rear cam roller bearing support the outer cam journals.

I, for one, do not want to give up the new oil pump with 10% more feed and 23% more scavenging capabilities. However, the 2006 Dyna and 2007-to-present cam support plates do not use support bearings and remain a concern in my mind. We will have to wait and see if they prove as reliable as the ball bearing-roller bearing setup. As of 2010, there does not seem to be problems but Moment Arm Force may still oblong the holes. I am remaining on the sidelines as to whether these components are an overall improvement until we see the wear characteristics of the new parent material bearings in the cam support plate for the outboard cam journals.

Perhaps the next generation timing-chest components will have the new style bigger 1.000" rear cam journals, the new hydraulic chain tensioners with the roller chains, and the new oil pump combined with a cam support plate with a front ball bearing and a rear roller bearing like the late 2000 to 2006 cam-support-plate. This design updates the good but less effective earlier oil pump; will get rid of the problematic silent chains, spring-loaded tensioners, and the new parent material support for the outboard cam journals.

The cam support plate bushing (25344-99) that has use from 1999 to 2010 in all Twin Cam engines now eliminates in favor of parent material in 2011. The inner diameter (ID) of the parent material remains the same as the support plate bushing. Furthermore, all service cam support plates will have parent material as opposed to a bushing. Therefore the new 2011 TC96, TC103, and CVO 110 cam support plates will retrofit back to the 2006 Dyna Glide.

The TC96, TC103, CVO 110 Oil Pump-A Blowby Solution?

The original 1999 oil pump (26035-99) has gone through various improvements (26035-99A, 26035-99B), through the years. The 2006 Dyna and 2007-to-present oil pump (26037-06) will not mate to the 1999 to 2006 cam support plates.

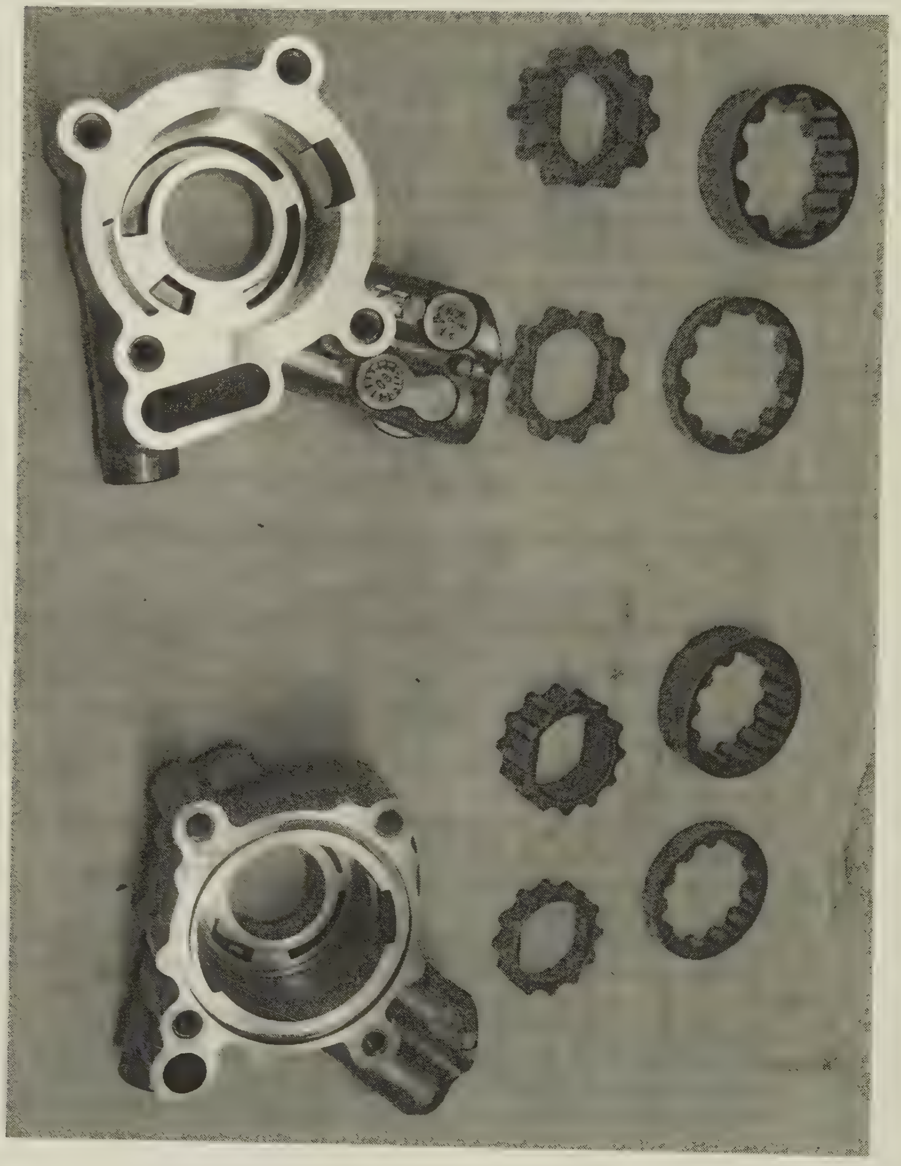
The new oil pump is superior. It has a different porting arrangement than earlier ones. The H-D 26037-06 oil pump, pumps 10% more oil on the feed geroter set. Geroters replace the Evolution oil pump spur-gear arrangement. Geroters are lobed gears that run one-inside-the other to create high oil pressure and high oil volume.

Perhaps its biggest benefit will be in attempting to control oil carryover also known as blowby or external venting where an oilified mist and sometimes-straight oil is expelled from the top-end breathers into the air cleaner and out onto the side of the engine. The TC96 oil pump has 23% improved scavenging capacity that will leave less oil sloshing around that may mix with transferring air. The geroter pairs are narrow and flat.

The two feed geroters are about a quarter-inch thick while the two return ones are double that.

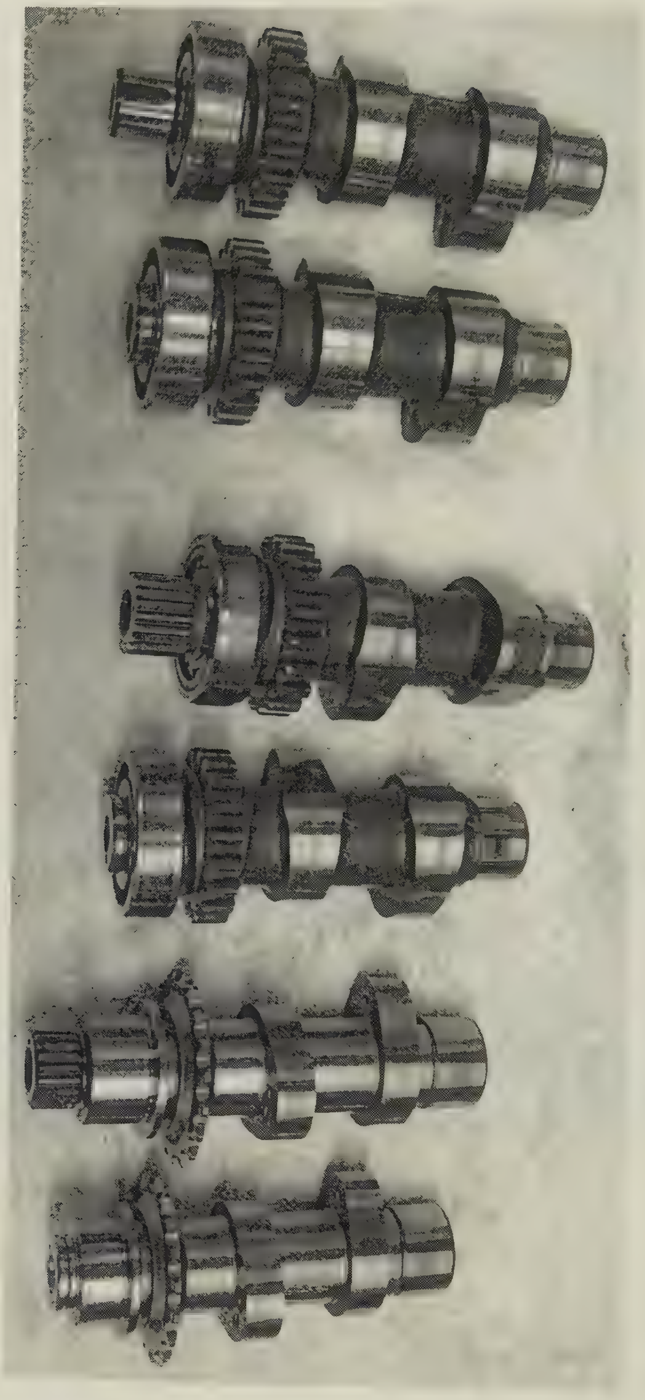
1. One rotor sits within the other with a total diameter of about one and three-quarter inches.
2. The outside rotor is round on its outside perimeter.
3. The outside rotor's hollowed out center has internal nubs much like a belt drive belt.
4. The hollowed out, smaller inside rotor is round on the inside with two opposing flats that mate with and sit on the pinion shaft drive. The rotating pinion shaft drives the oil pump.
5. The outside perimeter has external nubs that interact with those on the inside of the outer rotor.
6. The mating nubs move in a seemingly eclectic but steady pattern because the inner geroter has one less nub or lobe than the outer.
7. The meshing lobes open to let in oil and close in on each other squeezing trapped oil out to make pressure.
8. The 1999 to 2006 (except the 2006 Dyna) oil pump has a 12/13-lobe interaction. The outer geroter has 13-internal lobes while the inner geroter has 12-external lobes.
9. The 2006 Dyna and all 2007-to-present Big Twins use 10/11-nub rotors. More oil feeds in between because extra space creates. The return side increases flow by 23% because the rotors are thicker than the feed geroters that increase flow by 10%.

Thus, more oil removes from the timing chest and returns to the oil tank on the 2006 Dyna TC88, and the later TC96, TC103, and CVO 110 engines. This prevents as much oil from pushing into the top end and overwhelming the oil-separator-breathers by the voluminous air displacing inside the engine.



Comparing Early and Late Twin Cam Oil Pumps

Pictured on the top is the 2006 Dyna-2007-to-present Twin Cam oil pump (26037-06) while the one on the bottom is the basic pump (26035-99A) in use from 1999-2006 (except the 2006 Dyna). All previous oil pumps for Harley-Davidson except the 1977 to present Sportsters employ gears to pump moderate volume and moderate pressure. The geroter style-oil pump impels higher volume and pressure in use on all Twin Cams and 1977-to-present Sportsters. Oil feeds into spaces between the geroter nubs. Oil entrapment occurs as the rotors turn. The rotating nubs force the oil into an increasingly smaller space before opening a passage for it to escape creating the higher pressure and volume. The 2007 style pump also creates more oil volume and pressure than the earlier Twin Cam pump because the geroters have the same outer diameters but use fewer nubs. Fewer nubs allow more oil to enter thus entrapping a greater amount of lubricant. The 1999 to 2006 pumps have a 12/13-lobe interaction. The outer geroter has 13-internal lobes while the inner geroter has 12-external lobes. The new 2007 pump has 10/11 nub rotors so 10% more oil feeds into the engine. More oil (23%) removes from the timing chest and returns to the oil tank. The return geroters are thicker than the feed geroters, thus they can handle more oil. H-D hopes this will control blowby since not as much oil will be available to carry up into the rocker boxes alleviating the danger of the breather apparatus becoming overwhelmed. This will definitely help. An easy way to identify the pumps is on the return side housing (shown). The early pump has a round oil return-hole while the new pump has an elongated hole to accommodate the increase in scavenging on the left side as viewed in the picture. The holes align to their respective cam support plates



A Brief Pictorial Twin Cam History of Camshafts

The 1999 to early-2000 cam set (top) used two ball bearings to support their outboard cam journals in the cam support plate. The rear cam ball bearing proved problematic and was prone to breaking apart. The cam drive gear fit on the end of the rear cam via a female keyway slot. This led to the shearing of the male keyway cast into the 34-tooth sprocket affecting engine timing and ability to run. The middle set of cams is late 2000 to 2006 (except 2006 Dyna) and utilizes a roller bearing on the rear cam journal with a ball bearing supporting the front cam. The rear cam-drive sprocket fits via a splined shaft fixing the previous keyway-shearing problem. The bottom pair of cams is used on the 2006 Dyna and 2007-to-present Big Twins. The front and rear cam outboard journals (left side) increase from their previous size. The larger diameter outboard journals fit into holes (parent material bearings) cut into the cam support plate. The inboard cam journals (right side) that fit into INA bearings in the inner right-hand engine casing also increase in size from the previous .875" to 1.000". The late inboard cam chain sprockets are noticeably thinner. The early TC88 cams are one-piece construction. Each late cam is 5-piece construction with pressed on cam lobes and sprockets and one cam journal end. Metallurgical and hardening differences between the cam lobes and the cam journal ends tailor to particular and different functional stresses.

TC96 Engine Synopsis

There is no appreciable gain in horsepower of the TC96 over the TC88 although air delivery improves, compression increases, and there is more swept volume. Rider perception will not agree with this as the bike feels faster and *in fact is faster.*

1. This is because of repositioning of flywheel weight for more instant throttle response, an increase in torque generated by the TC96 engine and the steroid primary engine and clutch sprockets married perfectly to the 6-speed gear ratios.
2. Increasing the stroke to achieve more cubic inches will reduce piston longevity.
3. Decreasing the crank's reciprocating weight will partially offset this.
4. Improvement of the heads bases on the existing casting design with much needed increased flow. The heads still need opening up more to get true potential.
5. The timing chest plagued with wear problems since the Twin Cam's inception vastly improves.
6. However, the loss of ball and roller bearing support for cam journal ends may create a new boondoggle.

Overall, we have a much-improved motorcycle with more torque that closely matches with a usable powerband via the gear ratios transferring the power back to the rear wheel. Despite my criticisms, I think it the fastest and most functional Big Twin of all time.

CHAPTER XIII

2008 Model Changes

There will be many small changes or modifications not noted here. I do not really learn about their nuances until taking the machine apart, which I will do a few times this coming winter.

Bigger Gas Tank

The touring gas tanks are now six U.S. gallons (23 liters), up from five U.S. gallons or 19 liters.

Torque Ratings

The 2007 touring models torque rating is 91 ft-lbs @ 3000-rpm.

This increases in 2008 touring models to 92.6 ft-lbs @ 3500 rpm.

1. The 2008 torque rating for the Dyna series is 92 ft-lbs @ 3000rpm.
2. The 2008 Softail series lags behind at 86 ft-lbs torque @3200 rpm.
3. Touring models generate more torque measured at the engine than the Dyna models because of the larger capacity mufflers.

The counterbalanced Softail model engines always lag behind because of internal frictional loss of horsepower. The engine must expend the energy to drive the counter balancers. This robs the engine of torque and horsepower that would otherwise generate without the drag of the counter balancers.

Isolated Rear-Belt Pulley

The rear drive-belt sprocket pulley has six rubber dampers incorporated to form an isolated drive system (IDS). The rear pulley has six stops cast in it on the inside portion facing the rear wheel. Between the rear wheel and pulley, encased in its own holder are the six stationary dampening rubbers that buttress against the pulley stops when assembled together. Sudden movement in the rear-drive train cause the pulley stops to compress the rubbers absorbing energy.

I hope that this innovation will reduce vibration and noise from acceleration, cruising and of course, while shifting. This IDS rear pulley system has been used successfully on V-Rod models. Early reports on Twin Cam usage are positive but we must wait for the mileage to pile up before declaring this as a total success.

The rubbers absorbing the sudden strain on the drive train softens the traditional Harley clunk when engaging a gear especially from neutral. I have already discussed, perhaps the real reason for this Isolated Drive System in Chapter X: *The Controversial Harley 6-speed Transmission*, section; *The IDS Fix or is that an Enhancement?* I postulate that this is a powertrain harmonic pulse dampener that stops returning refraction back up the powertrain thus silencing the Cruise Drive 5th spur gear clatter.

Compression and Gear Ratios

The compression ratio remains the same at 9.2:1
There is no change in gear ratios either.

Brembo ABS Brakes

The big news in 2008 is that an Anti-lock Braking System (ABS) is a standard feature on the Touring CVO 110 cubic inch (1803cc), Screamin' Eagle models as well as the VRSC V-Rod. ABS is an option on all other touring models and on all VRSC V-Rods in 2008.

The well-known performance brake manufacturer, Brembo worked with Harley-Davidson to develop this new braking system. The Motor Company uses the same brake master cylinders and the Brembo brake calipers on both ABS and non-ABS equipped models.

Unlike many other manufacturer ABS systems, the Brembo-Harley one is not a linked one. A linked system engages both brakes when only activating the front or rear brake lever/pedal. The H-D non-link system allows full and independent control of the front or rear brake if engaged separately. The Factory introduced an ABS system, on police bikes a few years ago but the new system for 2008 is less bulky and largely hidden. The new Brembo ABS now replaces the old ABS on equipped police bikes.

I think most of us are familiar and comfortable with ABS on our cars or trucks. Experienced riders may intellectually know that ABS offers safer and superior stopping but may be uncomfortable giving up rider control to a computer. New riders will think that ABS is the way it has always been. These same fresh riders learning on an ABS equipped Harley may also be in for a shock when first riding a non-ABS equipped older models in adverse conditions. Demonstrations on a slippery gravel surface using a Harley equipped with stabilizing outriggers makes obvious the differences between the superior ABS brakes and standard ones. Observing braking on this gravel surface with the ABS Brembo-Harley system demonstrates a controlled stop without the outriggers coming into play. The same rider then demonstrates a stop on the same surface without ABS brakes. It becomes immediately obvious that the bike is no longer under control as the outriggers save the rider from a possible accident.

ABS Braking Stops Faster

Coincidentally, the ABS system often stops the bike in less distance. The ABS allows maximum braking in undesirable conditions without locking the bike's wheels into a skid. The wheels and hence the tires actually move at a velocity of up to twenty percent less than the speed of the motorcycle. This speed difference is the braking force in action. Thus, the rider is able to maintain control of the bike during deceleration as the main and overriding ABS purpose is safety.

I find ABS a wonderful assist in adverse braking conditions such as stopping on gravel, oily road surfaces and of course, in the rain…and how about those autumn wet leaves on winding turns. To state the obvious, a skidding wheel has less traction and control on a slippery roadway than a non-skidding wheel.

ABS operated brakes prevent brakes from fully functioning when the tire has broken loose from its contact patch with the road surface better known as skidding. The brakes return to full capacity as skidding ceases thereby allowing a faster stop with the added benefit of allowing steering to function.

Wheel Sensors

The wheel sensors determine when a wheel, more specifically the tire is about to lock up into a skid. The wheel sensor senses rapid deceleration of the wheel beyond normal, which indicates a locking skidding condition, is about to commence. The sensors feed this information to a computer that operates valves within the braking system that eases brake pad pressure by moderating the fluid pressure activating them.

As the wheel begins to accelerate again, indicating traction, the sensors notify the computer, which actuates the valves to increase brake fluid pressure fully activating the brake piston and pads on the disc. These actions happen very fast with the goal of keeping the tire slowing in proportional tandem with the motorcycle, which is what efficient braking dynamics is all about. The H-D ABS system reacts every 1/100th of a second to any changes occurring.

I consider myself a good Harley-Davidson motorcycle rider...and a lousy sport bike rider...but I must admit that I cannot react in less than a second to changing conditions. Therefore, the ABS will react 100 times faster than my best time. Furthermore, I cannot anticipate with absolute precision when a wheel is about to commence a skid. Testing has demonstrated repeatedly that even a professional racer cannot stop as fast on a slippery surface with traditional brakes as with ABS equipped brakes.

As good as ABS is, braking too hard in a turn, for example, may still result in wiping out but H-D engineers use the non-link braking for rider control in low-speed riding maneuvers.

ABS Pulsing

There is a different feel on the brake lever and pedal when ABS activates known as pulsing. Pulsing may also be audible. A slight tire chirp is also normal sometimes when activated.

Rapidly opening and closing internal valves causes brake-pressure modulating: this results in the pulsing at the brake lever and pedal. This swift opening and closing modulation of the valves acts constantly in controlling imminent skid. An ABS cycle occurs when the computer closes the fluid valves when the wheel decelerates and is about to begin a skid and opens the valves when the wheel begins to accelerate indicating cessation of the skid. These sensor-computer generated actions happen so fast that there may be as many as seven cycles per second. The cycling is what gives the pulse sensation at the brake lever and/or pedal. The pulsing sensation on the new 2008 ABS equipped models is not as pronounced as on many vehicles but it is still there.

The brakes feel the same, whether the bike is equipped with ABS or not in normal situations. The rider will only feel the difference on an ABS equipped Harley if wheel skid is impending. An experienced Harley rider may gently pump the brakes in a slippery situation mimicking what an ABS system does so much more effectively. Pumping does not work with an ABS system. Hold the brake firmly when braking and the ABS will do all the work. Pulsing sensations indicate this and that all is well.

ABS Module

Gone is the bulky police model ABS module located in the saddlebag. It replaces with a smaller module that inserts away behind the right-hand side cover on touring Twin Cam models and behind the steering head on the VRSC V-Rod.

Traditional, ABS systems usually have some sort of a toothed-sensor system incorporated into the brake disc outer edges or near the center of the disc rotor. The non-linked system eliminates this unsightly-to-some toothed brake discs in favor of wheel-speed indicator sensor rotors incorporated onto a molded wheel-bearing spacer on each wheel.

The spacer cap ring has alternate polarized magnetized segments. These sensor rotors are not visible to the rider. A sensor reads the magnets sending wheel speed information back to the ABS control module.

If looking for ABS on a 2008 model, the only indicators are a warning light on the faring dash and sensor wires behind the front fork sliders and the rear swing arm. The dash light is an indicator of whether the ABS is functional or not.

ABS Self Diagnostic Check

When starting an ABS equipped Harley, the system does a self-diagnostic check for functionality and safety. The warning light flashes during this check. The test completes by the time the bike reaches 3 mph. The warning light stops flashing when the diagnostics are completed and deemed secure. If the light continues to stay on after this, the system has detected a fault. The ABS deactivates and automatically reverts to non-ABS functionality until servicing and remedying the problem.

A critical mechanic-friend who is familiar with ABS on other model Japanese and European motorcycles took a new CVO Ultra Classic Electra Glide for a test ride. He felt that the Harley-Brembo system works as well as others he has used.

Fly-by-Wire Throttle Control

Another biggie in 2008 is the introduction of a fly-by-wire throttle control also known as Electronic Throttle Control (ETC). This replacement of throttle and idle mechanical cables combines with a customizing feature we have been doing in custom shops for twenty years.

Internal Handlebar Wiring

The handlebar wiring now routes inside the bars for aesthetic cleanliness on 2008 touring models. Interestingly, the Motor Company stopped using internal handlebar wiring after 1972 in favor of external handlebar wiring harnesses utilized from 1973 to 2007.

Dynas, Softails and Sportsters still use outside throttle cables in 2008.

Fly-by-wire throttle is not anything a traditional Harley rider is familiar with and probably has never heard of including the name. Briefly:

1. H-D has eliminated the throttle cables for an electronic actuator.
2. The rider turns the throttle as always for acceleration, cruising, or deceleration.
3. H-D even places a spring inside the throttle housing, which is now larger to provide a little resistance so the experience will be seamless for the rider.
4. Two Hall effect sensors inside sends a signal to the electronic control module (ECM) indicating throttle opening or closing.
5. The ECM activates the servomotor, which incorporates into the side of the Delphi induction module. It opens and closes the induction module throttle plate.

Cruise Control

A mechanical advantage to the fly-by-wire throttle control is that it simplifies cruise control making it easier to implement on the motorcycle. One little glitch that will still need some work is that when the electronic throttle is used with cruise control there is a small lag time between when the throttle is turned and actual acceleration.

New ECM and EFI

There is a new electronic control module (ECM), on the 2008 models that controls the fly-by-wire throttle control, cruise control and engine parameters most importantly the engine air-to-fuel ratio. The new system will be much more difficult to re-map for performance upgrades or simply changing to a friendlier AFR ratio.

The Future is Here

Harley-Davidson is introducing the 1125R Buell a water-cooled motorcycle in 2008. While not a Twin Cam, this is a harbinger of the future as peripheral models adapt to new emissions controls, mandatory in 2010.

Liquid cooling and a production radiator had first use with the V-Rod. Now with the 1125R it is going to spread insidiously, leaving no motorcycle unaffected in future years. Water cooling traditional Harley-Davidson's is just the way it is going to be, my friends. Of course the Great Recession causes the demise of the Buell and stalls implementation of liquid cooling but the V-Rod marches on.

Chapter XIV

2009 Model Changes

Superficially, there does not appear to be any major changes with the 2009 Twin Cam models. Nothing could be further from the truth. There are many new and sometimes-subtle changes that the rider and/or mechanic should not take for granted.

If working on any of the new Harley-Davidson's for the past few or future years do not assume that specifications are not constantly changing. Always consult the Harley-Davidson manual. I constantly find innocuous changes. One reason is that H-D is wisely keeping traditional appearance a priority.

The New Twin Cam Touring Frame

The FLT touring frame has not appreciably changed in 29-years since its introduction in 1980. It has now supported three different engines, each faster and more powerful than the one before.

1. A CVO 110 has almost double the horsepower and torque of the original Shovelhead engines that had basically the same FLT frame fitment.
2. The new 2009 frame is stronger and increases the GVWR (gross vehicle weight rating) by 100lbs (45.5 kg), to 1360lbs (617 kg). Furthermore, this assists in increasing cargo carrying capacity by 15lbs, 5lbs for the tour box, and 5lbs for each saddlebag.
3. The frame is now two pieces. There is a separate tail section.
4. The previous FLT frame consists of 90-different castings, stampings, and bent pieces of tubing.
5. There are no bent pieces of tubing on the 2009 FLT-series frames. There is only straight tubing that is larger in diameter and thus stronger. Cast and forged modular node-tube joints hold the new frame together.
6. There are about half the parts in the new frame with half the welds. The new frame backbone skeleton builds around a single spar that begins as 2-stamped pieces, welded together.

I hate to say this but eliminating the human element with coordinated motion robotic MIG welding ensures accuracy, welding quality and chassis alignment.

Two-Piece Frame

This is primarily for possible future design flexibility on the part of the Motor Company. Changing rear tire size or rear mounting of component parts like the battery box, fender, saddlebags, and tourpak is now a simple procedure. Only a small separate part of the frame needs redesign instead of the whole enchilada.

Customizers will have fun with this also, as the possibilities expand exponentially. The rear end of the new touring bikes will become a customizing hotbed of new ideas and looks.

1. The frame is reportedly 20% stiffer for better handling at speed and in the corners. I can report that the new frame handles a great deal better.
2. Geometry stays much the same with a steering rake of 26°. However, trail increases .7" to 6.9", again for more comfortable handling.
3. The rear fork is much beefier and two-piece construction. The manufacturing lingo is the fork is from a deep-drawn shell with a forged pivot section.

Engine Isolation-mounting System

Handling and vibration control improves once again by *expanding the previous three-mount-system to four.*

The single center upfront isolation mount replaces with two side-mounted vertical isolation supports.

1. One mounts at the base of each frame downtube and tie together with a single link.
2. Now each of the four corners the engine have isolation-supports instead of a shaky triangle.
3. The new supports are supposed to last the life of the motorcycle. This is great but I must say that I have heard this type of claim before notably for the early disastrous 1999 to 2006 Twin Cam spring-loaded timing chain tensioners. Logically, the new isolation mounting system will last much longer since there is extra support that does not allow wide swings in engine vibration especially at idle.

The improvement effect is most noticeable at idle. The engine does not shake as it has from 1980 right up until 2008.

H-D nomenclature can get really overworked and take on new meanings over time. The 1980 to 2008 T in FLT or FLHT signifies that these models and their many derivatives is a rubbermounted version of the original Shovelhead Electra Glide the FL or FLH.

However the T is an acronym for *three* as in a triangular rubber mounting system. Now we have an FLHT series of touring bikes that are not triangularly mounted but quad-mounted.

Shocks

There are now dual adjustable air shocks replacing dual non-adjustable air shocks.

Internal Engine and External Rider Cooling

Harley-Davidson did not make any one comprehensive fix for internal heat problems that are injurious to rear cylinders and heads, particularly on the CVO 110. Nor for external ones that protects the rider from engine and exhaust heat-dissipation. However, there are a series of adjustments, re-designs and partial fixes that combine to provide relief internally and externally.

In fairness, the one overall fix that would eliminate heat-related problems is not available to the Factory as it violates EPA and CARB regulations. This, of course, is lowering the Stoichiometric 14.7:1 air-fuel-ratio to increase the cooling gas relative to air mixture. Therefore, the CVO 110 continues to receive patchwork Band-Aid measures that dance around the heat issue. Please see Chapter IX: *Synchronizing Ignition and Fuel Delivery*, section: *The (EMS) Engine Management System (2009)* for more information.

EITMS (Engine Idle Temperature Management System)

The Engine Idle Temperature Management System is now rider controlled. The EITMS feature located in the stock ECM or electronic control module can turn on-or-off via the throttle grip. Once enabled, the rider can turn off fuel delivery to the rear cylinder *when the bike is idling.* There are new ECM fuel and ignition calibrations for 2009. Please see Chapter IX: *Synchronizing Ignition and Fuel Delivery*, section: *2009 Heat Management System: Engine Idle Temperature System* for more information.

The Oil Reservoir

Oil re-circulates more efficiently because of a baffling redesign inside the oil reservoir. Oil enters the oil pan and flows circuitously over the top of a baffle plate to the rear where oil flows down into the lower baffling to make up to nine tortured flow-turns, crisscrossing the oil pan back-and-forth for pickup at the front of the pan.

1. Original Evolution oil reservoirs that locate below the transmission had no baffling whatsoever. The result was that some oil did all the work whereas other portions of the oil simply languished in the tank.
2. Baffling introduced circa-1999, forced oil to distribute heat more evenly for added efficient dissipation.
3. The newest baffling redesign now mixes oil thoroughly in order to assist in heat dissipation and the suspension-removal of dispersed contaminants from engine wear and combustion blowby.

The Exhaust

Twin Cam riders have all been complaining since 1999 about sometimes-insufferable heat emanating from the engine and the exhaust. The rear exhaust- header-down pipe afflicts the rider from the right side while the crossover pipe extends out to distress the rider from a left side vantage point.

The 2009 touring bikes address this burning issue from the exhaust through superlative multifunctional design.

1. First, there is a performance increase via a collector accepting both front and a *forward swept* rear pipe that mercifully takes the exhaust header away from the rider's right thigh.
2. The rear header pipe extends forward in front of the transmission and down to the frame rail to begin extending back.
3. The rear crossover pipe leaves the collector underneath the bike to connect with the left side rear muffler.
4. The right pipe extends back from the collector to connect with the right side rear muffler.

The design also relieves some heat from the passenger making his or her ride more pleasant as a result.

1. There are fewer joints between pipes to seal and clamp. The 3-joints, five if including the header to head connections, connect each muffler plus the rear crossover pipe to the collector.
2. A fresh exhaust port gasket (65324-83B), still bases on the initial Evolution design in 1984. Air leaks sucking cooler air past exhaust joints cause the exhaust popping so common with deceleration.

3. New Torca clamping assists in tighter connections and popping should reduce also with fewer tighter fitting joints.
4. The front exhaust shield is now one-piece completely covering any pipe bluing from the rider's eye.

The only criticism I might have that will be born one way or the other over time is that the crossover pipe might have exposure to damage as it is unprotected by frame members.

California bikes have the catalytic converter inside the collector. Those bikes with the catalytic converter will now be able to meet emissions dictates with some aftermarket mufflers since most of the pollution control now occurs before the mufflers. I predict the rest of the world will also soon have a catalytic converter as EPA dictates tighten once again.

Rocker box shields

The Ultra Classic, Police, and CVO Ultras also have rocker box shields on either side of the rear rocker box in front of the seat to deflect engine heat for rider comfort. These mid-frame air deflectors are installed during the pre-delivery inspection (PDI) on Ultra Classics,

TC96 Engine

Flywheels

The endplay specification of the flywheel side play inside the engine casings increases to .003" to .013" (.076mm to .370mm), from .003" to .010" (.076mm to .250mm). This extra .003" endplay is a significant change although it may seem small.

New retrofit flywheels will accept the now old long compensator hold down bolt or a new short bolt. Early 2009 flywheels will come with the longer bolt as the Factory uses them up.

The compensator assembly absorbs engine shock as torque transfers out the sprocket shaft and down the power train. Sometimes, this compensator (40296-06) has been bottoming out.

1. There have been temporary fixes by adding an extra spring/shim.
2. The 2009 compensator (40296-06A) is now 7% stronger.
3. Some hope, this move will control power pulses that made the IDS rubber mounted rear pulley necessary to dampen Cruise Drive 5th gear noise. We shall see but so far so good in late 2010.

Screamin' Eagle Compensator Fix: 2008

This beefy compensating assembly, part number 40274-08, works so much better than the stock original TC96 compensating sprocket assembly 40296-06 and the improved one, 40296-06A. If I may go so far as to say, in comparative terms, it showcases the weakness of the stock early and upgraded late TC96/CVO 110 compensators I do not think I would be exaggerating.

Obviously a new alternator rotor comes with the upgrade since it is integral with the compensator housing and springs. The original 6-speed models have a 4-spring pack compensator-rotor for both domestic and H-D International models. The S.E. upgrade incorporates two very large outside spring washers with one set about the diameter of unit, a medium size spring washer and one smaller one. The design appears to be progressive in order to complement larger TC103 and CVO 110 motors down to the relatively smaller TC96 units. The compensator ramps also change. Start up bang should be a thing of the past for many and along with the touring models IDS should make the experience even better.

This new S.E. compensator is massive and in my opinion should been used in the first place on the TC96 models and especially the CVO 110. However, it is standard equipment on the 2009 103c.i FLHTCUTG Tri Glide Trike

The good news is that it will retrofit to:

1. 2006 to present Dynas.
2. 2007-to-present Touring models.
3. Most Softail models except the FXCW, FXCWE and the FXSTSSE[3].
4. This S.E. compensator will be the best yet at controlling the engine pulses of a wide variety of build sizes. Some owners report their bikes feel stronger, with no start-up bang. Others that have installed the S.E. compensator on 2007 models without the IDS rear pulley dampener system report a slight tick sound. This would suggest that the new compensator is successful in controlling engine pulses traveling down the powertrain and reverberating back up into the transmission thus reducing fifth-gear click substantially.

To take this further, a reinforced and stronger compensator may have been the cure all along making the IDS largely unnecessary. However, being a typical Harley rider where more is always better, it is nice to have both.

Defective Ring Gears

Some starter gear rings located on the clutch hub outer casement were not heat-treated correctly. This of course, will cause ring gear tooth damage and loss. This situation is now corrected.

Please see the following section, *CVO 110 Engine* for updates on rocker boxes, gasketing, and automatic compression releases.

TC103 Engine

The TC103 engine powers the 2009 FLHTCUTG Tri Glide trike that I will discuss in detail further on in this chapter. Any changes I discuss in the previous section *TC96 Engine* is applicable to the TC103 also. The TC103 gains its 7-extra cubic inches from re-boring the TC96 3 ¾" diameter cylinders out the 3 ⅞".

CVO 110 Engine

Finally: Valve Springs are Clearanced

My, my the lower rocker box (17573-99A) is now relieved for valve spring clearance, eliminating inefficiencies and noises due to a valve spring retainer *touching* the rocker box. Forgive my sarcasm but I spend much time relieving rocker boxes on these engines to eliminate noise and possible breakage.

1. The CVO 110 receives this change as of December 17, 2007.
2. TC96 and TC103 engine chrome rocker-boxes receive this change as of March 7, 2008.

3. A new rocker box gasket (16719-99B), matches the rocker box. Be careful not to use the traditional gasket with the new rocker box.
4. The rocker box will retrofit but the new gasket will not.

Cylinder Base and Center Case Bolt O-rings

I hope that cylinder base oil-weepage and leakage will eliminate as:

The old black cylinder-base round O-ring replaces with a new orange quad ring.

1. As well, a smaller orange cylinder base drain dowel-pin quad-ring replaces its predecessor black round O-ring.
2. The kit (HD-11907) contains these square quad-rings, two for the base and two for the dowel sealing.
3. There is also a center case attachment bolt O-ring to quell leaking from this area. Please refer to dealer only TT370, May 13, 2008 and TT372, May 22, 2008 for CVO 110 Twin Cam service updates. TT is the acronym for Tech Tip.

Another New Head Gasket

Mercifully, there is a new head gasket replacing the otherwise excellent flat-surface metal MLS head gasket. The new graphite head gasket (16801-07B) retains the same service procedures, torque sequences and torque specifications. In my opinion, this is a Band-Aid approach but a necessary one, nonetheless, in controlling head gasket leakage from the rear head oil-return dowel-pin. The gaskets are excellent but cannot cope with a warped head.

Automatic Compression Release (ACR)

Many ACR's on 2007 and 2008 CVO 110's are defective and may release compression while the engine is running or not work when supposed to ease starting.

The automatic compression release (ACR) solenoid (28861-07A) began production as of January 28, 2008. It revises for both the TC103 and the CVO 110. The latest ACR replaces part number 28861-07 and has a new wire boss shape, which requires a new installation tool, part number HD-48498A.

Another New Head

There is a fresh cylinder head for the CVO 110, which has valve guide changes allowing cam lifts up to .596". The front cylinder head with a new functional ACR is part number 17251-07B indicating this is the third head in use in three years. The rear cylinder head, again with the new functional ACR is part number 17252-07A indicating it is only the second head in use for the current 3-year production of the CVO 110. This is odd since it is the rear head that has been having the heat-related problems.

The Factory makes no note of different casting materials to withstand the excessive heat plaguing the rear-shrouded cylinder head. This sometimes warps the head gasket surface causing the old MLS gaskets to blow outwards from the oil-return drain dowel-pin.

- The new valve guides allow the extra cam lift capability. The tolerance to remember is .080" clearance beyond the valve lift measuring between the top of the valve guide seal fitment over the valve guide and the underside of the top valve spring retainer.

- The new shorter intake valve guide identifies by a machine groove on the intake-head-port end of the guide.
- The exhaust guides are longer to combat the extra heat stressing.
- Both the shorter intake and longer exhaust guides now have retention clips.
- The lower valve collar fits under the retention clip. It is normal to have up to .070" tolerance-play between the collar and the retention clip.
- *There are no oversize valve guides for this head.* Unbelievably, new head replacement is necessary when the guides wear beyond tolerance. I am sure the aftermarket will fill this void.
- The old valve guides taper on their port ends. This assists in air flow. The new valve guides do not taper and square on their port ends…one step forward, one step back.

Compression

Heat is the enemy of the CVO 110 as it causes cylinder liner flexing and warping of the cylinder head gasket surface. This causes the rear head gasket to blow outwards from the oil return dowel pin.

As I have written many times, compression produces heat because increasing compression creates pressure. Heat and pressure is the same thing. Expanding heat creates pressure and pressure creates heat.

Twin Cam Compression Ratios

	Engine	c.i size	cc size	Bore	Stroke	Compression
H-D	TC88	88c.i	1450cc	3 ¾"	4.000"	8.8:1
H-D	TC95	95c.i.	1550cc	3 ⅞"	4.000"	9.4:1
H-D	TC96	96c.i.	1584cc	3 ¾"	4 ⅜"	9.2:1
H-D	TC103	103c.i.	1690cc	3 ⅞"	4 ⅜"	9.8:1
2007 H-D	TC110	110c.i.	1800cc	4.000"	4 ⅜"	9.3:1
2008 H-D	TC110	110c.i.	1800cc	4.000"	4 ⅜"	9.3:1
2009 H-D*	TC110	110c.i.	1800cc	4.000"	4 ⅜"	9.15:1

*The exception is the 2009 FLHTCUSE[4] whose compression reduces to 9.2:1 from 9.3:1.

In a bid to further control CVO 110 heat issues, the Factory reduces compression from 9.3:1 to 9.15:1 on the 2009 FXDSE, FXSTSE[3], and the FLTSE[3].

H-D reduces compression on the 2009 FLHTCUSE[4] from 9.3:1 to 9.2:1.

On a normal engine like the TC96, which has a 9.2:1 compression, this is not of major concern. However, on a high performance engine like the CVO 110, lowering compression will certainly assist with heat issues but it is counterproductive to producing torque and horsepower.

Any engine, I would build in the 110 cubic inch realm would certainly have a minimum of 10.5:1 compression to develop the necessary oomph one would expect from an engine this big. Of course, dual 10-core turbulated oil coolers, a larger oil reservoir, ignition and fuel modifications and other changes need to go hand-in-hand along with metallurgical and design changes.

The real problem is it is impossible to build fast big-inch, 45° air-cooled H-D engines and stay within EPA and CARB guidelines. Harley-Davidson continues the increasingly difficult task of satisfying traditional customer wants with modern emissions dictates.

Three 2009 Updates for 2007-2008 CVO 110 Engines

This section may initially sound confusing but if the reader digests one paragraph at a time, all will be well.

Harley-Davidson is pretty good with warranty claims and tries to resolve most legitimate customer issues although they do have their moments…and it appears that they are having one with the CVO 110. In my opinion, many times the Factory will not admit to some problems but work hard in the background until there is retrofit fixes that sometimes H-D refers to as an enhancement. This delay can cause much rider frustration especially when the H-D owner does not know there is an upgrade in the works. Usually, the design of the *enhancement* has the purpose of extending engine longevity and dependability.

The problems with the first two years of Screamin' Eagle CVO 110 engines is a case in point. Leaking rear head gaskets and warped rear head gasket surfaces are impossible to ignore. Again, these are symptoms of the causal factor, heat that is mandated by the EPA to burn more harmful emissions.

However, the symptom of the shifting upper-portion cylinder liner is ignored with this particular H-D fix. If the head gasket surface of the rear head will not warp, then it really ceases to become an overt symptomatic problem.

The July 28, 2008 Service Bulletin M-1225: *2007/2008 CVO 110 C.I. DISPLACEMENT ENGINE UPDATE PRODUCT PROGRAM 0905* seeks to upgrade 2007 FLHTCUSE[2] and 2008 FLHTCUSE[3] models built before April 9, 2008 at no cost to the customer. Harley-Davidson will have sent a letter to all registered owners advising of this. This free upgrade is for two years after the date of this Service Bulletin, which means it was good until July 27, 2010.

If you are unclear whether your CVO 110 falls under this update, consult any H-D dealer with your VIN (serial number). The dealer can access the service tab called UltraComm on www.h-dnet.com, which is a secure Harley-Davidson website to determine if your bike needs this upgrade.

I don't think there will be much customer confusion. If your CVO 110 has at least 10,000 miles on it and there is no rear head gasket oil leak then you are most likely not affected. The upgrade kit basically replaces the old heads with updated heads and new ACR automatic compression releases along with new hopefully improved gasketing and the top center motor case bolt.

There is a different *full* upgrade (repair) kit for 2007 and 2008 CVO 110's. The 2007 CVO 110 upgrade kit is HD-94676 for the 2007 FLHTCUSE[2] and the 2008 kit is HD-94675 for the 2008 FLHTCUSE[3] models built before April 9, 2008.

This is pretty straightforward until the reader gets into the next partial upgrade covering other Screamin' Eagle models. I had to read everything over about three times before understanding, so please be patient.

There is a separate fix for both 2007 and 2008 specific date Screamin' Eagle CVO 110 models; 2007 FXDSE, FXDTSSE, FLHRSE[4] and the 2008 FXDSE[2], FXSTSSE[2], FLHRSE[4] models built before May 14, 2008 and 2008 FLHTCUSE[3] models built between April 9, 2008 and May 13, 2008. This upgrade kit as outlined in the July 28, 2008 Service Bulletin M-1226; *2007/2008 CVO 110 C.I. DISPLACEMENT ENGINE UPDATE PRODUCT PROGRAM 0906* does not include new heads. I cannot understand this as in my experience these models also have head failures. The HD-94677 kits include some specific gaskets for either year but not both so there will be extra gaskets at the end of this *enhancement* procedure.

2007-2008 Screamin' Eagle CVO 110 Upgrade Enhancements

CVO 110 Upgrade Kits		2007-2008 Kit: 94677 [1]	2007 Kit: 94676	2008 Kit: 94675
Qty.	**Description**	**Part number**	**Part number**	**Part number**
1	Rear head + ACR	NA	17252-07A [2]	17335-08A
1	Front head + ACR	NA	17251-07B [2]	17336-08A
1	Top-end gasket set	17349-07	17349-07	17349-07
1	Clamp	10038A	10038A	10038A
1	Screw, hex flange	1090A [3]	1090A [3]	1090A [3]
1	Gasket	29313-95	29313-95	NA
1	Gasket	29645-08	NA	29645-08
1	Gasket	29583-01A	29583-01A	NA
1	Gasket	29718-08	NA	29718-08
2	O-ring	11292	11292	NA
1	Gasket	29059-88A	NA	NA
1	Gasket	29593-05A	NA	NA
2	ACR solenoid	28861-07A	NA (included)	NA (included)
2	O-ring	10925	NA	NA

[1] This kit covering both 2007 and 2008 specific date S.E. CVO 110 models (2007 FXDSE, FXDTSSE, FLHRSE[4] + 2008 FXDSE[2], FXSTSSE[2], FLHRSE[4] models built before May 14, 2008 and 2008 FLHTCUSE[3] models built between April 9, 2008 and May 13, 2008) does not include new heads.

[2] I don't get why the problematic rear head is 2nd generation denoted by the "A" suffix on the part number while the normally okay front head is 3rd generation denoted by a "B" suffix. I would think it would be the other way around but what do I know?

[3] On the 2007/2008, 2007 and 2008 upgrades, the top center engine case bolt replaces with the supplied 1090A screw, hex flange. Specification torque is 15 to 19 ft-lbs (20.3 to 25.8 Nm). The 1090A screw (bolt) replaces the OEM 1090, 5/16"-18 x 3 ¾"screw, hex flange (2007 to 2008), which replaces the predecessor OEM 895, 5/16"-18 x 3" screw, hex flange in use since the advent of the Twin Cam in 1999.

The clamp (H-D 10038A) is a gas line clamp for the equalizer line at the front of the gas tank, which must be removed in the disassembly process.

Gasket 29313-95 is an HDI part that fits between the air filter and the air filter backplate assembly (backing plate) for the 2007 update. This gasket saw first use on all 1995 Big Twin Evolutions.

1. Therefore, gasket 29645-08 is also an air filter gasket seeing first use in 2008. It is for the 2008 CVO 110 update.
2. Gasket 29583-01A is the 2007 update gasket for the air cleaner backing plate to the EFI induction model that saw first use as 1st generation 29583-01 in 2001.
3. Gasket 29059-88A is for the air cleaner backing plate.
4. Gasket 29593-05A is another air cleaner gasket. The kits must have gaskets to cover numerous models and applications.
5. Gasket 29718-08 is the 2008 update gasket for the induction module to the air cleaner back plate.
6. The two O-rings (H-D11292) are for the 2007 update to seal the breather bolts that screw into each head from the inside of the air cleaner. These are not provided or needed for the 2008 update, as there are different breather bolts and sealing system.

CVO 110 Cylinder Condition

There is an H-D specific testing procedure to determine if deglazing cylinders and new ring installation is necessary. H-D specifies a comprehensive leakdown test in Service Bulletin M-1226 that determines if compression is seeping by the rings. Power is all about compression. This 3-phase leakdown test is really three tests in one whereby leakage is tested with the piston rings at TDC (top dead center), half way down the cylinder bore, and at BDC (bottom dead center). Do the in-between mid-stroke leakdown test with the bike in 6th-gear and the rear brake activated. Leakage of 10% or more in any of the three positions requires deglazing and new rings.

What do I do? I deglaze all removed cylinders and I use new rings *all the time in every instance.* Fresh bored cylinder bores require that the top compression ring be moly (molybdenum) while deglazed cylinders should use cast top compression rings, which are softer.

The Transmission

There is a new transmission top vent line (62372-09) as well as new transmission locking rings (2), with serrations on one face. The smooth side faces the gear.

1. The Softail and Dyna models retain the same internal gear ratios in use since the introduction of the 6-speed Cruise Drive transmission.
2. Touring models have new gear ratios that result in better acceleration for the heavier bikes.
3. There is also a new 68-tooth rear pulley. It requires a 140-tooth rear belt. This changes secondary and final gear ratios. Please see the charts below.

USA Sprocket Sizes: 1999-Present

SPROCKET	NUMBER OF TEETH-DOMESTIC MODELS				
	1999 EFI	2005	06 Dyna	2007-08	2009
Engine	24	25	34	34	34
Clutch	37	36	46	46	46
Transmission	32	32	32	32	32
Rear Wheel	70	70	68	66	68

The reason that 2006 Dynas and 2007 and 2008 Big Twins have differing gear ratios is because of a 2-tooth/nub reduction in the 2007 rear wheel pulley. The 2009 models go up 2-nubs on the rear pulley and have the same size pulley as the 2006 Dyna Gide. This will improve acceleration for the 2009 models.

Sprocket/pulley Sizes

Primary: Secondary and Final Drive Ratios

SPROCKET	NUMBER OF TEETH-USA MODELS					
	1999 EFI	2005	06 DYNA	2007 2008	2009	DD6	S&S
ENGINE	24	25	34	34	34	28	25
CLUTCH	37	36	46	46	46	36	36
Primary ratio	1.54:1	1.44:1	1.35	1.35	1.35	1.29	1.44:1
TRANSMISSION	32	32	32	32	32	32	34
REAR WHEEL	70	70	68	66	68	70	70
Secondary ratio	2.19:1	2.19:1	2.13:1	2.06:1	2.13:1	2.19	2.06
Final drive ratio	3.37:1	3.15:1	2.88:1	2.79:1	2.88:1	2.83:1	2.97:1

The reason that 2006 Dynas and 2007/2008 Big Twins have differing gear ratios is because of a 2-tooth/nub reduction in the 2007/2008-rear wheel pulley. The 2009 models go up 2-nubs on the rear pulley and have the same primary, secondary and final drive ratio as the 2006 Dynas.

USA Overall Gear Ratios

HDI (H-D International) models generally have taller gearing for better highway touring because of increased speed limits. HDI models usually have smaller rear wheel pulleys than those used in USA.

Internal Transmission Ratios for each gear

Performance is all about increased horsepower and torque. The third component, drive ratios, delivers this power in a way specific to the rider needs and wants.

Gear	1999 TC88	2006 Dyna	2007-08 TC96	2009 FXST/ Dyna	2009 Touring	S&S	BAKER
1	10.11	9.87	9.31	9.31	9.59	11.51	10.60/9.70
2	6.96	6.80	6.42	6.42	6.65	7.88	7.20
3	4.95	5.09	4.77	4.77	4.94	5.76	5.26
4	3.86	4.17	3.93	3.93	4.00	4.37	4.05
5	3.15	3.46	3.28	3.28	3.41	3.49	3.23
6	NA	2.88	2.79	2.79	2.88	2.97	2.81
RPM	@75mph 3227	@75mph 2951	@75mph 2859	@75mph 2859	@75 mph 2951	@75mph 3043	@75mph 2879

Overall gear ratios show the number of engine revolutions required to turn the rear wheel one 360-degree turn. For example in 1st gear all 2007 to 2008 Twin Cams and 2009 FXST/Dyna models take 9.31 engine revolutions to rotate the rear wheel once while a 2009 Touring TC96 takes 9.59 engine revolutions to rotate the rear wheel once. A 1999 Twin Cam takes 10.81 engine revolutions to obtain the same goal in first gear. Overall gear ratios take into account the internal transmission ratios with the primary and secondary gear ratios while the final drive ratio is a simple multiplication of the primary ratio times the secondary ratio.

Cruise Drive 6-speed Transmission Gear Ratios

Gear	2007, 2008 TC96	2009 FXST, FXD	2009 Touring
1	9.312	9.312	9.593
2	6.421	6.421	6.650
3	4.774	4.774	4.938
4	3.926	3.926	4.000
5	3.279	3.279	3.407
6	2.790	2.790	2.875
2009 140 -tooth Rear Belt Tension Specifications			
FLHX	Bike upright, rear wheel raised		1/4”-5/16”
All others	Bike upright, rear wheel raised		1/4”-7/16”

Increasing the Juice

Alternator (Rotor + Stator) Charging Amperage by Year

Year	Model	Amperage	Stator	Voltage
1970-1975	Shovelhead	15	29965-70	12
1976-1980	Shovelhead	17.8	29965-75	12
1981-1988	Shovel + Evo	22	29965-81B	12
1986-1990	Sportster	19	29967-84A	12
1989-1996	Evo FLT carb.	32	29970-88C	12
1989-1999	Evo Softail	32	29970-88C	12
1991-2006	Sportster	22	29967-89	12
1991-1998	Evo Dyna	32	29970-88C	12
1997-1998	FLHT-FLT	38	29987-97	12
1999-2001	FLHT-FLT	40	29987-99	12
1999-2003	Dyna	32	29951-99	12
2000	TC88 Softail	32	29951-99	12
2001-2006	Softail	38	30017-01	12
2002-2005	FLHT-FLT	45	29987-02	12
2006-2009	FLHT-FLT	50	29987-06B	12
2008-2009	Softail/Dyna	40	30017-08	12
2007-2009	Sportster	30	29997-07A	12

The Big Twin dumped the generator after 1969 and began use of alternating charging systems in 1970. The Sportster used a generator until the end of 1983 and switched to an alternating charging system in 1984.

The 1970 to 1988 Shovelhead and Evolution touring models had progressively increasing amperage stators of 15amps, 17.8amps and 22amps. These are deficient for the needs of a touring bike with spotlights, radio/stereo and other running lights. However, the low amperage rates are sufficient for sporty bikes like the FX and FXR's. Harley-Davidson began to get serious with the 32amp stator in 1989 with all models. The charging-discharge cycle of the electrical system began to even out. However it is the touring models that need more amperage. The chart demonstrates that the touring bikes get more respect and thus more amperage than other models beginning around 1999. Look at the last three entries with the Sportster using a 30amp stator, the Softail and Dyna requiring a little more juice with a 40amp stator and the big touring bikes with all the accessories getting the biggest amperage of all at 50amps.

Early Evolution batteries often needed replacement every year. This was for two reasons. First vibration shook the batteries causing sulphation and internal shorts. Ergo rubbermount model batteries lasted longer than rigid mount Softails. Secondly, the electrical draw requirements were greater than the charging capacity of the too-small alternators. The electrical system needs discharge-recharge balance for battery longevity. Always check H-D parts manuals for the correct charging system parts especially after 1997 as identifying the charging parts required for a specific year and model is not as simple as from 1970 to 1996. The end plug of the stator will always differentiate different year stators. If replacing a stator with a wrong one, the plug will not work in the regulator/rectifier.

2009 Tire and Wheel Information

New Model and Year Specific Tire Tread

The 2009 FLHRC Road King Classic as well as the FXDF Dyna Fat Bob, and the FXDFSE Screamin' Eagle Dyna Fat Bob use a new front tire tread on the 130/90 B16 tire. Tire psi fill requirements are:

Front touring models are 36lbs.

1. Rear touring models is 40lbs for solo rider and 2-up.
2. Rear FXDF, FXDFSE is 36lbs for solo rider and 40lbs for 2-up.
3. This front tire tread will not retrofit correctly to earlier models because it will not match older rear tire treads. Furthermore, do not attempt to put older model tires on the 2009 FLHRC. There are new Dunlop tires on all touring models. They are model specific. Be very careful, checking with the manufacturer for matching tire availability if retrofitting forward or back in years.

All other touring models excepting the FLHRC (16" wide-white-wall tire) now use a new cast 17" (130/80-17) front wheel.

Touring Model Rear Wheel and Associated Parts

1. The rear tire is now a whopping 180, with a lower 65 profile that fits on a new 28-spoke 5.00" wide, 16" rear wheel.
2. The new rear tires are *multi-tread.* This means the center part that has use when traveling straight is a harder compound for longer lasting wear characteristics while the sidewalls are softer and stickier gripping for turning purposes.
3. Furthermore, there is a new rear wheel lacing procedure that will catch mechanics offside without consulting the H-D manual.
4. The wheelbase increases by .5-inches.
5. Of course, this wider fat rear wheel necessitates a fatter rear fender that closes gaps and becomes sleeker.

Softail FXCW Rocker and FXCWC Rocker Custom

There are new tire direction specifications for the FXCW and FXCWC. Consult your manual. The tread design on the 2009 FXCW and FXCWC reverses from 2008. Any mechanic will inadvertently put this tire on backwards through many years experience in observing tire tread patterns. This will lead to many incorrect tire installations in the future for those that do not study new technologies and procedures.

There are many new and sometimes-subtle changes that the rider and/or mechanic should not take for granted.

Rear Pulley Changes

The 2009 compensator gear remains at 34-teeth, as does the clutch sprocket at 46-teeth.

The rear drive transmission-pulley also remains at 32-nubs but the rear pulley increases by 2-nubs from 66-nubs to 68-nubs resulting in better acceleration. The increase in pulley size requires a new 140-tooth length belt.

The primary, secondary, and final drive ratios are now the same as in used on the introductory 2006 Dyna models. Please see the above gear ratio charts.

The IDS (Isolated Drive System), rubber mount rear drive pulley compensator is now part of the rear wheel hub and separate from the rear drive belt pulley. The rubbers in the compensator absorb power pulses from the engine traveling down the power train. Before developing the IDS, pulses were returning back up from the former rigid mount rear pulley causing the Cruise Drive 5th spur gears to chatter. The pulley is now just a pulley with no dampening function.

2009 Front Tire Pressure Chart

Model	Tire Size	Front PSI
FXCW, FXCWC	90/90-19"	30lbs
XL1200L, 1200N, 1200R, XL883, 883L, 883R, FXD, FXDB, FXDC, FXDL	100/90-19"	30lbs
FXST, FXSTB, FXSTC, XL1200C, XL883L	MH90-21"	30lbs
FLST, FLSTC, FLSTN, FLSTSB	MT90 B16	36lbs
XR1200	120/70 R18	36lbs
VRSCAW, VRSCDF, VRSCDX	120/70 ZR19	36lbs
FLHRC, FXDF, FXDFSE,	130/90 B16	36lbs
FLTRSE[3]	130/70 B18	36lbs
FXSTSSE[3]	130/70 R18	36lbs
FLHP, FLHR, FLHT, FLHTC, FLHTCU, FLHTK, FLHTP, FLHX, FLTR, FLHTCUSE[4]	130/80 B17	36lbs
FLSTF	140/75 R17	36lbs

2009 Rear Tire Pressure Chart

Model	Tire Size	Rear PSI	Rear 2-up
Sidecar	130/80 B17	28lbs	28lbs
FLST, FLSTC, FLSTSB, 883C, 883L, 883R XL883, XL1200C, 1200L, 1200N, 1200R,	150/80 B16	36lbs	40lbs
FXD, FXDB, FXDC, FXDL	160/70 B17	36lbs	40lbs
XR1200	180/55 R17	38lbs	42lbs
FLTRSE[3]	180/55 B18	40lbs	40lbs
FLHP, FLHR, FLHRC, FLHT, FLHTC, FLHTCU, FLHTK, FLHTP, FLHX, FLTR, FLHTCUSE[4]	180/65 B16	40lbs	40lbs
FXDF, FXDFSE	180/70 B16	36lbs	40lbs
FLSTC, FLSTN	MU85 B16	36lbs	40lbs
FLSTF, FXST, FXSTB, FXSTC	200/55 R17	38lbs	42lbs
FXCW, FXCWC, FXSTSSE[3], VRSCAW, VRSCDF, VRSCDX	240/40 R18	38lbs	42lbs

Do not exceed the maximum *cold* tire inflation pressures that the rider will find molded or branded into the sidewalls of all tires. Front tire pressures are always a few pounds lighter than the recommendations for the rear, as weight distribution is less. These inflation figures are a base generalization only for average size riders and passengers. Conditions will modify the pressure up or down. For example, high-speed riding or very high temperatures may require a moderate increase in pressure. Follow tire manufacturer recommendations. Sizing may indicate in inches, metric, or by code alphanumeric lettering. For example, if tire width is 5.00-inches, this translates into 130mm in metric. The alphanumeric letter coding is MT for 5.00", which is the same as 130. Tire width is always the first part of the sizing nomenclature. Tire height or aspect ratio to width is the second. Aspect Ratio equals the height/width x 100. Tire height usually expresses in metric millimeters (mm). Therefore, if the stock height or aspect ratio Harley tires designates as 90, this translates into 3:25 inches. A lower profile, (height or aspect ratio), of 80 is smaller with 70 smaller again and so on.

Tires: Inch, Metric, and Alpha Designations

Example	Designation	Motorcycle	Width	Aspect Ratio	Rim	Load Rating	Speed Rating
5.00H164PR	Inch		5.00		16	4PR	H
130/90-16 67H	Metric (mm)		130	90	16	67	H
MT90-16 B	Alpha	M	T	90	16		

PR = ply rating. The letter B sometimes precedes the last figure, which identifies the rim diameter or comes after it. B indicates a bias ply tire. The letter R indicates a radial tire.

Motorcycle Speed Ratings

Letter	Speed mph	Speed kph
J	62	100
N	87	140
P	94	150
S	112	180
H	130	210
V	149	240
Z	149+	240+

The acronym kph stands for kilometers per hour. Older H-D tires had an H rating, which means the tire can run at sustained speeds of 210 kph or 130 mph. A V rating indicates sustained speed capability at 240 kph or 149 mph. Therefore, wide safety margins exist for H-D tires since they can never achieve the speed ratings.

Common Harley-Davidson Tire Sizing

Front Tire			Rear Tire		
Metric	Alpha	Width Inch	Metric	Alpha	Width Inch
80/90	MH 90	2.5/2.75	130/80	MT80	5.00/5.10
90/90	MJ90	3.00/3.25	130/90	MT90	5.00/5.10
100/90	MM90	3.25/3.50	140/90	MU90	5.50/6.00
110/90	MN90	3.575/4.00	140/85	MU85	5.50/6.00
120/70	MR70	4.00/4.25	150/80	MV85	6.00/6.25
130/70	MT70	5.00/5.10	160/70	70	6.80/7.00
130/80	MT80	5.00/5.10	180/55	55	7.00/7.25
130/90	MT90	5.00/5.10	180/65	65	7.00/7.25
140/75	MU75	5.50/6.00	180/70	70	7.00/7.25
			200/55	55	7.90/8.00
			240/40	40	9.80/10.00

Many charts from different sources and manufacturers vary on sizing and designations. Use this chart as a general guide only as no chart is completely accurate. There are some new rear tires for fitment on the FLHTCUTG Tri Glide trike whose wheels are matching cast aluminum 7-spoke units. The front is a 16" using a traditional MT90B16 tire. The dual rear 15" automotive style wheels fit with P205/65R15 radial tires.

Touring Models

The following upgrades and changes are miscellaneous ones not already covered in this chapter.

1. A new exhaust Torca clamp (65296-95A) has an assembly friction reducing coating for ease of installation that doubles as a secondary locking mechanism after tightening. Tightening torque is 38 ft-lbs to 43 ft-lbs (51.5Nm to 58.3 Nm).
2. The new shorter AM/FM antennas will retro back to 1998.
3. The CB will require removal of the loading coil in Tour Pak carrier. The CB antenna is marked for identification.
4. The new Tour Pak carrier support structure increases the rated payload by 5lbs. It still uses the current Tour Pak.
5. The rear lighting uses the current tail lamp and turn signals with revised light bars; new license plate mounting and the rear tip light are now LED.
6. The saddlebags move back .5". There are new support structures and guards. The rated payload increase for each bag is 5lbs.
7. There is a stator plug material change to correct the former plug's tendency to pull through the left engine casing.
8. Fork oil for Road King models is 11.0 ounces (125mm). Other touring models take 10.7 ounces (122mm).
9. The fork-stem nut now has no lock washer and the nut torque specification is 70 ft-lbs to 80 ft-lbs (94.9Nm to 108.5Nm).
10. The steering head adjustment now stops on the 3rd or 4th swing.
11. There is also a new fork triple tree.

Softail Models

There is a new common to-all-model electronic control module (ECM). The ECM has improved idle air control (IAC) software as a running change in January 2008.

The FLSTN has a new seat with *collapsible* sides. Collapsible pockets in the filler material relieve pressure to the rider inner thigh contact area.

New parts include, rear shocks and bumpers, exhaust Torca clamps and mounts, jiffy stand (sidestand) sensor, FLSTC front brake line, FLSTC handlebars, risers and top clamp; new front fender on FXST, FXSTC, and FXSTCB models plus other minor changes. This listing is not comprehensive with minor styling and functional changes. Consult your dealer.

Dyna Models

FXD, FXDC, and FXDL models have no new technical content. There are also new service procedures for the Dyna family. This may sound strange but the Dyna family has gone through many dramatic technical and model changes in the last three years.

1. All models have new silver-faced gauges. There is also a range-readout as part of the fuel tank sender indicator on the speedometer. Life is getting cushy on a Harley.
2. The FXDF Fat Bob and the CVO Fat Bob have new rear shocks.

FXDB

The FXDB Street Bob has a LED retro-style tail light with integrated LED stop-turn taillight signals on a novel bobbed rear fender.

There are no traditional chrome fender support covers.

1. There is a lower 25.8" solo seat.
2. Handlebars wire internally.
3. There are currently cool black wrinkled belt guards, battery cover, and fuel tank console with gloss black wheel rims.
4. The power train is black and silver without highlighted finning. Japan Harley's have highlighted finning.
5. Lastly there are mid-mount foot controls for riding stability, a custom air cleaner insert plus *chopped* straight-cut mufflers.

The FLHTCUTG Tri Glide Trike

The new design of the FLHTCUTG bases around an entirely new frame.

The Acronyms are out of Control

Boy-oh-boy, H-D is really stretching the limits of an acronym. It is okay for the old Harley people like me that can dissect the letters and break them down. FLHT is a rubber mounted base model-touring bike. C is the designation for an upgrade Classic, which includes a stereo and tourpak while the U is for the top model Ultra.

Whoops, used to be but not quite so anymore because of the FLHTUSE, which is a Screamin' Eagle Ultra. Mercifully, the Factory dropped the "I" as in FLHTCUI, which indicates that the bike/trike is fuel injected to separate them from carbureted models that do not exist after 2006. The TG stands for the Ultra Trike, more correctly known as the Tri Glide. Yep, the acronyms are getting too long for the ordinary Harley rider who must memorize all this stuff just so he or she can sound educated about their prestigious ride.

The Trike

The new chassis bases on a Lehman Trike design. Lehman's is one of the major trike players for Japanese and Harley two wheel motorcycles. I have installed Lehman kits for over ten years now. They are very safe and base on simple but effective technology.

However, I don't think they are as sophisticated relative to some competitor kits.

The Tri Glide is not a kit bike but a completely new motorcycle that brings excellent H-D design, fitment and paint coordination. They will serve the Harley rider well once steering improves a little more.

Steering

H-D has already made some of the prerequisite changes to improve steering geometry by reducing effort by a claimed 25%.

The front forks extend 1.775" over the two-wheel touring forks.

- Rake increases from 29.25^0 to 32^0.

The Flathead 45 Servi-Car

Harley-Davidson is not new to trike building. The Motor Company discontinued the 45c.i (750cc) flathead GE series Servi-Car production in 1973 after long and illustrious service.

Any readers that have ridden a four-five, which is Harley vernacular for this size engine, will know that they are slow and not capable of modern highway speeds.

The Tri Glide is a fast Harley. It is capable of excellent acceleration with the Cruise Drive 6-speed transmission and effortless high touring speeds thanks to the TC103 engine that is 2.3 times bigger than the four-five but delivers much more than 2.3 times the performance.

The four-fives used inefficient carburetion whereas the TC103 engine utilizes H-D's sophisticated engine management system with ESPFI (electronic sequential port fuel injection).

The Rear End

1. The new Tri Glide rear-axle assembly uses an aluminum center section with steel axle tubes.
2. Final drive is with H-D's new carbon fiber belt drive.
3. The rear suspension features the new 2009 dual air-adjustable rear shock absorbers.

Riding a Trike

A handlebar-mounted reverse module engages an optional electric reverse that integrates with the rear differential assembly. I find it surprising that this is a \$1200.^{00} option.

Everyone on a trike wants a reverse although I can say from experience that a trike is easy to muscle around unless suffering from a disability. However, pushing one backwards up an incline is not easy at all, so an experienced triker is always conscious of parking in favorable exit conditions. Traditionally, reverse systems for H-D aftermarket kit trikes have not been very good, which does not necessarily reflect on the functionality of the new optional H-D unit. Braking consists of the excellent stock touring dual Brembo front disc brakes and a Hayes dual-disc rear brake system with a lever actuating, integrated parking brake.

Trike riding is freaky at first when used to two-wheels. The rider may lean but it has no effect on steering anymore. The procedure becomes pulling on the handlebar end in the direction of turn and pushing on the opposite handlebar end. This must continue for the full radius of the turn as the trike will naturally begin to straighten out if pulling and pushing pressure lessens or stops.

Donny's Blasts from the Past: the Wrong Way to Ride a Trike

I had forgotten about this one until writing on how to steer a trike. The embarrassment lasted for many years.

Around forty years ago, the boys and I were on a run to a rock festival. We set up camp near a small lake and proceeded to imbibe. No one considered responsible drinking back then as plumes of marijuana smoke wafted through the hot summer air. Acid-rock bands played continuously in the background.

My buddy, Angel, was riding a chopped 45-trike with a raked and overly long springer front end. The spool front wheel-hub was brakeless in concert with the non-functional styling of the hippie era. Long upswept fishtail exhausts snaked up each side of the trike's rear beer box high into the air. The wild flame metallic-speck paint job made this trike a popular hangout location.

Angel told me to take her for a spin. I had never ridden a trike but that was not a concern. Macho testosterone laced with booze made the fateful ride's trajectory a foregone conclusion. I expertly kick-started the trike, activated the suicide clutch and hand-banger shifter whilst turning the deadman's throttle. I could do all this by rote even though I had much to drink.

Off I went towards a Johnny-on-the-Spot before the lakeside. No problem as I leaned to the right to circumnavigate the outhouse and make a wide sweeping turn away from the lake to go for a blast. The trike was not turning! I leaned further to no avail. The trike was gaining speed as my friends yelled steering instructions. Turning the front wheel would certainly result in the bike flipping. I had a two-wheel mindset on a three-wheel trike that could not lean. I rotated the deadman's throttle back to an idle position as I careened off the outhouse and finally settled with the front wheel in the lake. At least, I knew to turn off the throttle that aptly earned its name because it stays in whatever position the rider turns it to.

The whole rest of the weekend, I kept a brave face as I miserably listened to the countless retelling of my misadventure and the endless jokes about my riding skills or lack thereof.

Trike Wheels, Options, and Bodywork

1. The wheels are matching cast aluminum 7-spoke units.
2. The front is a 16" using a traditional MT90B16 tire.
3. The dual rear 15" automotive style wheels fit with P205/65R15 radial tires.
4. The Tri Glide, of course comes with all the Ultra staples and options like cruise control, GPS and a Harmon Kardon stereo.
5. The new Tri Glide rear end body components integrate nicely with the existing Ultra bodywork including the Tour Pak luggage compartment and the passenger seating area. I have built many trikes with kits and there is some skill to matching fiberglass rear ends to stock sheet metal.
6. The molded-composite rear trunk provides 4.5 cubic feet (127 liters) of storage space and accesses through a rear hatch.
7. The trunk and Tour Pak have 6.56 cubic feet (186 liters), combined capacity.
    - The current Tri Glide Ultra Classic FLHTCUTG comes in three colors, Vivid Black, Dark Blue Pearl, and Red-hot Sunglo.

CHAPTER XV

2010 Model Changes

Cruise Drive 6-speed Transmission Upgrades

I extensively cover the 6-speed Cruise Drive transmission in Chapter X: *The Controversial Harley 6-speed Transmission.* The advent of the 6-speed introduced first on the 2006 Dyna models and all Twin Cams in 2007 utilized helical gears on 2nd, 3rd, 4th, and 6th companion gear sets. Parts of mating helical gears are in full contact at all times eliminating troublesome gear lash induced noise generation. First and 5th gears are traditional spur types that are not full-contact and thus may make backlash noise before coming under load.

Helical gear sets create side thrust. This was the primary reason for the 5th gear set to remain spur cut. I have documented elsewhere, Bert Baker's opining that the snap ring configurations are too weak in the 2007 to 2009 Cruise Drive transmissions to handle helical gear accumulative side thrust forces. While, I am unaware of any problems caused by this situation, it remains a concern over time.

However, I have reports from an H-D dealership Service Writer/Adviser that by mid-2010, he began taking in 2008 and 2009 Twin Cams with transmission problems that included spun bearings and badly worn mainshafts and shifter shafts with lots of metal shavings present in the oil. While only about four motorcycles in one dealership with low mileage were affected by the time I was speaking to him, this may or may not be the harbinger of bigger problems to come.

His technicians felt the problems were due to the use of Syn 3 oil so they looked no further. The repairs were covered under warranty. I am no fan of using 20W-50 Syn 3 in a transmission because:

1. The transmission gears chop up the engine oil molecules causing premature loss of oil lubricity.
2. Both transmission fluid and engine oil require additives not conducive in both applications.

However, I cannot blame Syn 3 for these types of problems like spun bearings in relatively new bike transmissions. Yes, I would have loved to examine these transmissions because I feel there was another cause(s) but when I show up sometimes one would think I brought the plague with me.

The engine power pulses travelling down and back up the powertrain manifested themselves by an annoying rattle in the 5th spur cut gear sets. The rigid mounted rear wheel pulley allowed the transfer of these pulses back up into the transmission. Harley-Davidson's response was the IDS rubber mounted rear pulley, which effectively absorbed the pulses preventing their return into the transmission in most instances.

For 2010, Harley-Davidson has replaced the 2006 to 2009 5th gear spur-gear set with helical gears. In order to combat the extra side thrust generated by this change:

1. The transmission mainshaft snap ring groove has been moved inboard to the transmission inside approximately .090" for the purpose of providing additional support.
2. The different placement of the snap ring groove obviously requires a new mainshaft.
3. Furthermore, this spacing change necessitates adding a counterbore to the existing guide hub that fits over the main shaft. The shift dog ring rides on the guide hub. As I explain elsewhere, the guide hub is really a spacer that the shifter clutch dog ring moves back and forth on in order to engage its respective gears. The purpose is to eliminate clunky shifting that is so noticeable in 5-speed transmissions by making the shifter dog ring lighter and thus less cumbersome. Inertial forces are reduced by less mass having to move back and forth.

Is this 2010 improvement able to retrofit back into 2006 to 2009 Cruise Drive transmissions? Part of the upgrade is and part is not.

1. The mainshaft in conjunction with other mating parts is retrofitable back to 2006.
2. In fact, the mainshaft kit comprising of the new mainshaft, guide hub, snap ring and needle support bearing will be furnished for all replacement parts and 6-speed transmissions.
3. However, the part we want, which is the helical 5th gear set is not currently retrofitable for the following reasons:
    a) The speedometer will read incorrectly indicating a higher speed than is actually being traveled.
    b) The 6th gear light may or may not function properly.
    c) Currently, there is no recalibration available from Harley-Davidson although the aftermarket will be all over this one in short order.

In conclusion, the gears can retrofit back to the 2006 Dyna Cruise Drive 6-speed in conjunction with the updated main shaft kit but the speedometer will read faster that is until the aftermarket comes up with a recalibration modification. Finally, the first gear set remains spur cut for the following reasons:

1. These particular straight cut gears have caused no problems.
2. There are no substantial noise issues although ever restrictive EPA noise dictates may change this at some point in the future.
3. Changing these gears to a helical configuration will induce additional side thrust issues through the gear pack.

2010 Overall Gear Ratios

All 2010 Twin Cam models utilize the primary gear ratio of 34/46 in place since the 2006 Dyna Glide. The engine sprocket has 34-teeth and the clutch hub sprocket utilizes 46-teeth.

Overall gear ratios show the number of engine revolutions required to turn the rear wheel one 360-degree turn. For example in 6th gear a 2010 Twin Cam:

Trike takes 2.960 engine revolutions to rotate the rear wheel once. The resulting torque is 2.960 times the engine's output.

1. Touring model takes 2.875 engine revolutions to rotate the rear wheel once. The resulting torque is 2.875 times the engine's output.
2. Dyna or Softail takes 2.790 engine revolutions to obtain the same goal of turning the rear wheel 360°. The resulting torque is 2.790 times the engine's output.

Herein, lies the reason for varying the overall gear ratios. It has everything to do with vehicle weight and the number of engine revolutions to turn the rear wheel once. The gear reductions (ratios) are engine torque multipliers.

Acceleration is all about torque, the twisting force generated by the turning engine flywheels. One way to accelerate more quickly is to multiply the torque at low speeds to help move the vehicle forward.

This is why the torque multipliers are much higher in 1st gear and progress downwards to 6th gear. Lower gears require more torque to get moving and less speed as they get moving.

- Furthermore, torque multipliers are less as the gears progress higher because less torque is required in favor of more speed.
- Therefore, as my mama told me, you can't have everything. The motorcycle cannot have high torque and high speed at the same time but it can have a ratio of one to the other. Consequently, the overall ratio changes the torque multiplication from high torque-low speed progressively to less torque-high speed.

The reader will notice that all of the Trike ratios for each gear are higher than the Touring models, which are higher than the sportier model Twin Cams. Motorcycle weight is a huge factor in acceleration or power. The engine needs to generate more torque to move a heavier motorcycle.

2010 USA Overall Gear Ratios

Gear	Touring [1]	Trike [2]	FXD/Softail
1st	9.593	9.878	9.311
2nd	6.650	6.847	6.454
3rd	4.938	5.086	4.793
4th	4.000	4.118	3.882
5th	3.407	3.508	3.307
6th	2.875	2.960	2.790

The various CVO 110 models use the same overall gear ratios as their base TC96 models. A larger engine that produces more torque does not need the same gear ratios as a smaller engine with less torque. I think CVO 110 performance could increase with different gear ratios.

[1] The touring models are TC96 with the exception of the FLHTK with a TC103 powerplant.

[2] Both 2010 trikes have a displacement of 103c.i.

2010 USA Twin Cam Compression Ratios

Compression Ratio	Model	Displacement
9.2:1	FLHTC Electra Glide Classic	96c.i
9.2:1	FLHTCU Electra Glide Ultra	96c.i
9.2:1	FLHR Road King	96c.i
9.2:1	FLHRC Road King Classic	96c.i
9.2:1	FLHX Street Glide	96c.i
9.2:1	FLTRX Road Glide Custom	96c.i
9.2:1	FXSTC Softail Custom	96c.i
9.2:1	FLSTC Heritage Softail Classic	96c.i
9.2:1	FLSTN Softail Deluxe	96c.i
9.2:1	FLSTF Fat Boy	96c.i
9.2:1	FLSTSB Softail Cross Bones	96c.i
9.2:1	FXCWC Custom Wide Softail Rocker Custom	96c.i
9.2:1	FLSTFB Fat Boy Lo	96c.i
9.2:1	FXD Dyna	96c.i
9.2:1	FXDB Dyna Street Bob	96c.i
9.2:1	FXDC Dyna Super Glide Custom	96c.i
9.2:1	FXDF Dyna Fat Bob	96c.i
9.2:1	FXDWG Dyna Wide Glide	96c.i
9.6:1	FLHTCUG Tri Glide Ultra Classic Trike	103c.i
9.6:1	FLHXXX Street Glide Trike	103c.i
9.7:1	FLHTK Electra Glide Ultra Limited	103c.i
9.15:1	FLHTCUSE[5]: CVO S.E. Ultra Classic Electra Glide	110c.i
9.15:1	FLHXSE: CVO S.E. Street Glide	110c.i
9.15:1	FLSTSE: CVO S.E. Softail Convertible	110c.i
9.15:1	FXDFSE[2]: CVO S.E. Dyna Fat Bob	110c.i

It is remarkable that the biggest and therefore, most powerful engine, the CVO 110 has the lowest compression ratio. The three main ways to augment engine power is increasing:

1. Air flow with head work.
2. Swept cylinder volume (displacement or cubic inches).
3. The pressure in the cylinders known as compression.

The CVO has to lessen heat that causes engine-killing detonation. In order to meet emissions controls, the Stoichiometric air-fuel-ratio is used in the closed loop EFI to create the heat to burn as much harmful emissions as possible. This EPA is non-negotiable on allowable emissions. Therefore, the only other way outside of complete engine re-design to lessen heat is to reduce the compression-pressure in the cylinders.

The TC103 engines used in both trikes (FLHTCUG and FLHXXX) as well as the new FLHTK Electra Glide Ultra Limited utilize 9.6:1 and 9.7:1 compression ratios respectively, which is very high in light of emissions dictates.

I suspect that the 103c.i FLHTK with 9.7:1 compression will give the 110 cubic inch FLHTCUSE[5] with an anemic 9.15:1 compression ratio a run for its money.

Exhaust Catalyst

There are various cosmetic and design changes where applicable that I will describe for different models further on.

However, there are functional changes such as improved sealing and catalyst efficiencies. In fact the 2010 exhaust systems meet the crucial 2010 midyear EPA dictates for all Harley-Davidsons' sold in the USA 50-State's that include California. They meet Canadian standards also since they base on USA regulations.

Exhaust Catalyst

The 2010 exhaust systems also have an exhaust catalyst that locates for example in the new right side exhaust for the touring models. A catalyst exhaust system includes a catalyst housing having an inlet end, a passage, and an outlet end. The outlet end includes a valve seat.

An exhaust catalyst influences emissions depending on fuel composition and is a further refinement of oxygen sensor/Stoichiometric AFR/closed loop EFI to achieve the most efficient air-to-fuel ratios.

Exhaust catalysts must remain functional for at least ten years or 100,000 miles (160,000 km). Exhaust catalyst health and efficiency depends on a minimum of outside interferences like excess sulfur in the gasoline. As always, the push is on for a cleaner fuel. However oxygen intrusion must also be kept at a minimum. By this, I mean air leaks into the exhaust pipes through gasket and joint seals.

Exhaust Pipe Functional Air Tight Upgrades

1. The exhaust pipe endform that meets the exhaust port on each head is now spherical in shape to improve fitment and sealing capability.
2. Exhaust pipe consistency at the other end where meeting the muffler also improves. There is a developed rib and curl end presenting a positive muffler stop for joining the muffler to exhaust pipe.
3. The Dyna crossover exhaust joint improves sealing via a new gasket and clamp. Clamp torque specification is 15 ft-lbs to 19 ft-lbs (20.3NM to 25.8Nm).
4. The new Fat Boy Lo known as the Fat Boy Special in HDI and HDE countries has exhaust shields coated in Cermet, which is a high temperature ceramic coating. This may be more than a cosmetic change as ceramics hold heat in.
5. Softail models also have the new efficient endforms at the heads and at the muffler joints along with the new muffler clamp and gasket.
6. Softails mufflers have new internals with improved sealing at the exhaust catalyst with a new pipe to muffler seal.
7. The Softail Rocker crossover exhaust tube has the previous mounting wedges removed. There is a new interconnect gasket and clamps at interconnect joints.

Wheel and Tire Changes

Tire pressures are supposedly commonized across all models. However, this is not logical and does not seem possible. I looked in a 2010 Softail service manual for tire pressure information. Tire pressure ranges from 36psi to 42psi depending on the diameter and width of the tire. Consult your manual for specifics for your model.

Wheel weights are lead free. This is a running change so some may be and some not in 2010 although as time progresses lead obsoletes.

Wheel weights come in strips of segmented units. The early-2010 and previous lead weights are in .25oz (7gm) sections while the midyear (MY) 2010 and later segments are .07oz lighter at .18oz (5gm).

H-D Part Number Upgrade: December 2009

The Motor Company has been using the current part numbering system since the early 1960's. The spectacular growth of Harley-Davidson since then has added so many new parts that the system will run out of steam by sometime in 2012. In other words, all the numbers will be used up with new product requiring identification for the company, dealers, customers, and suppliers coming online on an ongoing basis. The new system is expected to carry through with H-D needs until the next century.

However, the current system will still be in use in conjunction with the new classification. The new system will apply to all new product coming online as of December 2009. Any part numbers assigned before this date including all the existing ones going back to the sixties will remain in use. Nothing will change with the existing method going forward.

Customers, dealers, and suppliers will notice the new part numbering system in the first few months of 2010. These new numbers will logically increase in use and quantity as rapidly as new numbers are increasingly required. At first, the old numbers will remain static for awhile and then slowly decrease as parts obsolesce. As time goes on, this process will speed up. New numbers will eventually become more numerous and dominate the old-system decreasing numbers.

Presently, general merchandise part numbers will not change as they still have room left to continue under the current (old) system.

The Current System

As the reader may be aware, the current numbering format generally is comprised of 5-numerals followed by a dash (-). After the dash are two numerals denoting the year of first use. The last two numerals may or may not have a single capital letter suffix, which denotes a minor change or upgrade to the original number for a particular part. The suffix A denotes a first change, B a second one, and C a third one. The system rarely has a need to go beyond an E suffix denoting the 5th change if so required. Therefore, there are a total of 8-characters to a part number (7-numerals, separated by a dash after the fifth number and before the last two numbers). Again, there may or may not be a suffix depending if a minor change has occurred to the original part.

This current format easily identifies the type of part if the reader understands the embedded code or sequence. It also allows the person looking at it to immediately determine year of first use. An example would be 98765-09 denoting first use as 2009.

The New System

The length of the part numbers do not change with the new system as one might expect. The new part numbering system also has just 8-characters. However, there is no dash (-) and no part number model year designation!

Maybe, I am like most H-D traditionalists and do not like change. The type of part and year of first use is not embedded in the new system formatted part number. Me, I don't like this but as always will adapt to it. The type of part and years of use for a particular model will be attributed on part number labeling, parts books, and in most cases with dealer management software. An example would be 98756000 denoting first use but with or without a suffix afterwards denoting change and subsequent use. Actually, the number would start near or at the lower end of the spectrum (example; 11111000) not the highest, which we wouldn't see for about 90-years.

Vehicle Identification Numbers

In 2010 there are a few changes in interpreting the VIN (vehicle identification number) 17-digit code.

1. The *pre-2009 8th digit* gives information regarding the motorcycle introduction date, which may be:
2. The regular date, which usually begins in July of the previous year.
    a) The MY (midyear) date, which is in the early spring of the production year. MY models usually incorporate some or all of the following year upgrades and changes.
    b) Special introductory dates that may be as simple as model cosmetic changes. These dates may occur at any time during the year.
3. The *post-2009 8th digit* also indicates engine management EPA, CARB, TÜV (Europe), or other country emissions calibrations in conjunction with the introductory date.
    a) The 8th digit may be a numeral from 1 to 6 or a letter from A to K. Each numeral or letter indicates one of the three possible yearly introduction dates in combination with engine management calibration for 49-State, California, Canada, HDI (H-D International), Australia, Brazil, or Japan models that all have specific government mandated requirements.
4. The 10th digit also changes from a numeral to a letter in 2010. Models in 2009 have a numeral 9 to indicate this year. The accepted worldwide uniform 17-digit VIN would necessarily increase to 18-digits if a 2010 model was signified by the numeral 10. This is not currently possible so numerals switch to the alphabet. Therefore, the 2010 model year is denoted by the letter A; 2011 by B; 2012 by C and so on.
5. The third and last change with the 2010 VIN number is with the 11th digit, which indicates the manufacturing plant the particular model was manufactured.
    a) Tomahawk Wisconsin was understandably denoted by the letter T up until the end of 2009. In a 2010 and later VIN, this delineation changes to an A.
    b) York Pennsylvania was denoted logically by a Y but is now changed to a B.
    c) Kansas City Missouri was denoted by a K but in 2010 and later models changes to a C.

- d) Many do not realize that Harley has a manufacturing facility offshore in Brazil. The plant is in the city of Manaus in the middle of the Amazon. Manaus was designated by the letter M until the end of 2009 when the designation changes to a D.
- e) Finally, Buell production, which is a moot subject since it has been discontinued in late 2009 resulting in the loss of 180 jobs, was manufactured in East Troy Wisconsin. In 2010, this designation changes to the letter E from the 2009 designation, the numeral 3. There will be regular 2010 introduction date Buell but not a MY date. The final Buell produced is a 2010 Lightning XB12CG. If wanting to see this bike, it has been donated to the Barber Motorsports Museum in Leeds, Alabama. It is one of twelve that also includes a 1991 X1 Lightning, a 1996 S3T Thunderbolt, a pair of modified Buell's ridden by stunt riders Craig Jones and Bubba Blackwell, and interestingly, several clay model prototype mockups.
- f) I cover vehicle identification numbers in great detail in Chapter XIX: Deciphering the Twin Cam Serial Numbers.

Touring Models

Touring TC96: 96c.i (1584cc) Rubbermount Engine/Chassis

The 2010 lineup includes the returning models, which are:

1. FLHT Electra Glide Standard (England, HDI, and Japan).
2. FLHTC Electra Glide Classic.
3. FLHTCU Electra Glide Ultra.
4. FLHR Road King.
5. FLHRC Road King Classic.
6. FLHX Street Glide.

A new model the FLTRX Road Glide Custom features:

1. The suspension lowers by 1". For those with short legs like me this is welcome indeed. The FLHX Street Glide is even lower at 27.3" (693.5mm) unladen seat height.
2. A low profile Dunlop D408F blackwall 130/80 fat 18" front tire/wheel. The FLHX Street Glide also features this tire as does the FLHR Road King but with a whitewall. Other touring models utilize a low profile Dunlop D408F NW (narrow whitewall) 130/80B 17" front tire/wheel except for the FLHRC Road King Classic that uses a standard profile and height front 130/90 16" wide whitewall tire.
3. All touring models use the same 16" low-profile, fat rear tire size, which is a Dunlop D407 NW 180/65B.
4. The fairing, outer and inner, is raised $^8/_{10}$" (.800") and tilted 2° forward. This accomplishes by:
    - a) Left and right side fairing brackets angle 1.5".
    - b) The mounting bracket for the inner fairing to frame has been clearanced on the bottom front edge of the mount.
    - c) As well the mounting studs move $^7/_8$" (.875") higher.

5. The headlamp mounting bracket has finally been modified to allow bulb replacement from the front without removing the fairing. This is a welcome change for mechanics and bike owners.
6. The dual headlamp bubble replaces with a shroud.
7. The head lamps are also different to tolerate exposure without the protective bubble.
8. A 2-into-1 exhaust with a single 4"-diameter chrome muffler that is now also on the FLHX Street Glide. This change also requires exhaust bracket modifications.
9. Both bikes also share a new rear light bar that includes turn signals and a new fender wiring harness.

Other changes include:

Smaller and compact heated, 4-wire, narrow band oxygen sensors replace the previous bulky narrow band sensors.

  a) They integrate into the exhaust pipe casting.
  b) A new tool (HD-50017) is required for torquing down the new smaller sensors.

1. Brembo front master cylinder plastic piston.
2. A running change in 2010 for a Brembo plastic rear master cylinder cap.
3. There is a passenger foot board bracket change with a new shoulder lower bolt. This allows the upper bolt removal to adjust the footboard bracket while the lower bolt remains fixed.

Touring 103c.i (1690cc)

The new touring model is the FLHTK Electra Glide Ultra Limited has a larger displacement of 103c.i (1690cc). The FLHTCU Ultra has been the top-of-the-line Harley-Davidson for many years now beginning with the 80c.i carbureted version in 1990 and the 80c.i EFI model in 1995. The Twin Cam TC88 FLHTCUI 88c.i introduced in 1999 with the Twin Cam TC96 taking over in 2007 with a 96c.i engine.

The FLHTK special standard features above the FLHTCU are;

1. ABS brakes.
2. A tour pack that includes a luggage rack and a 12-volt power supply.
3. Oil cooler with chrome accents.
4. Heated hand grips.
5. Unique two-tone paint.

Interestingly, from a power perspective, the FLHTK has the highest compression ratio of all 2010 Twin Cams at a remarkable 9.7:1.

Trikes: 103c.i (1690cc)

In addition to the FLHTCUG Tri Glide Ultra Classic introduced last year, 2010 brings a new trike, the FLHXXX Street Glide Trike. Handling improvements are addressed in a big way as is front wheel shimmy, a condition that most trikes suffer from:

1. The transmission casing goes through a redesign and reinforcement.
2. Engine mount design meets trike specific needs as do the *snubber* nuts. A snubber nut is used for dampening or cushioning a heavy object like an engine-mounted-along-a-hinge-axis-linkage like the engine mount via pivot shaft torque.
3. Suspension improvements balance with the 26^0 rake, which I thought would be more as increased rake tends to stabilize the trike chassis.

a) H-D addresses this 26° rake with a fork angle of 32° and a trail reduction to 3.94” (100.08mm). It accomplishes this through the fork crowns (lower triple clamp). The net effect is to optimize steering effort while reducing the steering angle. In comparison, two-wheel touring models also have a 26° rake with a fork angle of 29.2° for ease of turning at slower speeds but utilize a longer trail of 6.69” (169.93mm).
b) The 41.3mm telescopic front forks are extended, which has a net isolated effect of increasing rake.
c) The fork internals vastly improve for most touring models with triple-circuit dampening. There are distinctive lower forks (sliders), fork tubes, and internal springs. This is welcome as traditional H-D fork dampening is crude by modern technological standards.
d) There is an Ohlins front fork steering damper that will retrofit back to 2009.
e) There are air-adjustable tuned rear shocks.

4. The 103c.i engine produces 101 ft-lbs of torque at the output engine shaft. This is higher than one might think except compression increases to a respectable 9.6:1 that compares with 9.2:1 for the TC96 and 9.15:1 for the 110c.i engines.
5. The Final driveline utilizes a 70-tooth rear pulley with a 1 ⅛” rear carbon fiber belt.
6. There is a rear axle-differential assembly with rear drive compensation.
7. An electric reverse is optional although I think it will be standard equipment sooner rather than later, maybe by the time of reading. This is a little confusing because it is difficult to find a trike without the reverse installed. The reverse is an option. When the FLHTCUTG trike came out in 2009, H-D shipped trikes to dealers without the dealer actually ordering them. In the process, Harley added all available options and most if not all had reverse and security. For 2010, dealers order the units as they choose so I expect some to come without reverse but not too many because it is perceived as a necessity. I have built Lehman trikes for over ten years. I can categorically state that a reverse is not necessary as they move very easily. They are less cumbersome to back up than a two-wheeler. However, the bottom line is that the riding public wants a reverse gear.
   a) There is also updated reverse switch housing with different switch graphics that will retrofit back to 2009.
   b) The reverse circuit breaker relocates to under the right side cover.
8. The FLHXX Street Glide Trike has 4.3 cubic feet of trunk space.
9. Another problem with most trikes is a leaky rear trunk door. The trunk seal is improved for 2010 and retrofits to 2009 trikes.
10. There are matching front (3.00-16”) and rear (5.50-15”) cast wheels with rear wheel center hub caps.
11. The front tire is a Dunlop motorcycle tire (43022-91A) while the rear tires are Dunlop automotive 205/65R-15”.
12. New master cylinder and calipers will retrofit back to 2009. Brakes are Brembo dual 4-piston calipers on the front with Hayes floating single-piston-caliper rear disc brakes along with a necessary parking brake. These provide reduced brake effort, which is a big plus for women and the aging population.
13. The front brake rotors are 11.8” x .20” while the rear is 9.0” x .24”.
14. The inner fairing and fairing skirt are special in that there is triple clamp integration.
15. The speedometer calibration is naturally unique to the Trikes.

16. Exhaust pipes go through joint redesign to ensure proper sealing to prevent air leaks sucking in. Cooler air sucking in will disrupt EPA mandated emissions as well as cause the mufflers to *pop*.
17. There is no front fender bumper on either trike in 2010. Therefore, the 2009 FLHTCUTG front bumper is now removed.
18. The FLHTCUTG Tri Glide has a traditional style fixed metal passenger grab mount that bolts under the seat to the frame with hold-on extensions coming up on either side. The FLHXXX Street Glide has the less functional but sportier style grab strap in keeping with its sleeker styling.

Softail Models

Softail TC96B: 96c.i (1584cc) Counterbalanced Engine/Rigid Chassis

The 2010 lineup includes the returning models, which are:

FXSTC Softail Custom.

1. FLSTC Heritage Softail Classic.
2. FLSTN Softail Deluxe.
3. FLSTF Fat Boy.
4. FLSTSB Softail Cross Bones.
5. FXCWC Custom Wide Softail Rocker Custom.
6. FXST Softail Standard (Australia and Japan only).
7. FLST Heritage Custom (Brazil only).

Two Softail models discontinue after 2009:

1. FXCW Custom Wide Softail Rocker.
2. FXSTB Softail Night Train.

One new model introduces:

1. FLSTFB Fat Boy Lo marketed as the Fat Boy Special for HDI and HDE (H-D Europe).

The FLSTFB Fat Boy Lo/Special features:

1. The Fat Boy Lo has a lowered (1.15") suspension by using FLSTN shocks. Seat height is a remarkable 24 ¼". The HDI and HDE Fat Boy Special is not lowered.
2. The motif is Denim black painted parts and satin chrome. Oil tank, headlight (except the bulb-ring) fork covers and wheels are blacked out.
3. New contoured seat.

There aren't many changes except for paint to the Softail lineup but they include:

1. The top engine mount to frame bracket is zinc-plated to offer superior clamp load retention. The previous bracket hold down fasteners must have had a tendency to come loose.
2. There is a new horn isolator rubber mount along with a new horn with the breather hole relocated from the diaphragm to the bottom side of the connector.
3. FLSTC fuel tank panels upgrade with UV protection for the leather and ABS backing along with front mounting-hole changes.
4. FXCWC left hand front fork sliders have a change in brake caliper mounting-hole radiuses.

5. There are a bunch of small changes like a new positive battery cable router, front brake line clip, an upgraded master cylinder cap and gasket, and bobtail rear fender protective lighting wiring harness grommet.

Dyna Models

Dyna TC96: 96c.i (1584cc) Rubbermount Engine/Chassis

The 2010 lineup includes the returning models, which are:

1. FXD Dyna.
2. FXDB Dyna Street Bob.
3. FXDC Dyna Super Glide Custom.
4. FXDF Dyna Fat Bob.
5. FXDL Dyna Low Rider (Japan only).

One new model introduces: a 2010 FXDWG Dyna Wide Glide whose features are:
The frame has a 34^0 rake offering 5.2" (132mm) trail.

1. The frame fuel tank mounting boss is raised ¾" (.750").
2. The rear frame forgings are moved out by 2mm over the FXDF Dyna Fat Bob.
3. Front forks are shortened by 1".
4. The 21" x 2.15" front wheel is steel with chrome spokes accentuating a black rim and a neutral machined hub.
5. The rear fender is new. It is no longer bobbed like on every other Wide Glide model over the years. The upsweep is gone.
6. USA models have a side mount license plate assembly. This is the reason for the move away from the fender bob since the fender must now cover the tire instead of the license plate bracket/taillight. The HDI/Canada taillight is nostalgic and chopperish reminiscent of the nineteen-thirties. It mounts on the rear fender.
7. Internally wired handlebar.
8. Short round tube sissybar arches back. If a passenger is looking for comfort, this is not it. The seat rail is more cosmetic than functional.

Dyna models feature:

1. Belt tension specifications commonize to the FXDB Dyna Street Bob specification.
2. Front fork oil levels change as do some torque specifications. Consult service manual for different model specifications.
3. FXD 2009 rear shocks (54517-06) change to H-D 54615-01.
4. FXDC 2009 rear shocks (54512-90A) change to H-D 54615-01 also.
5. FXDL 2009 rear shocks (54534-09) change to H-D 54615-01 also.
6. FXDB shocks (54615-01) remain the same as in 2009.
7. FXDWG shocks are also commonized to H-D 54615-01.
8. The exception to commonization is the FXDF shocks (54537-08A) that remain the same as in 2009.
9. There are wider mounting tunnels on all gas tanks with an assembly paint protector.
10. All models with laced wheels utilize 7-pin connectors between the inner and outer uniform floating expansion brake rotor.

11. FXDB 17" x 4.5" rear wire wheel has a black rim with accentuating chrome spokes. The tire is a 17": 180mm wide, 60mm low profile (180-60 x 17").
12. Michelin tires are used on all but the FXDF and FXDWG Dyna models.

CVO Screamin' Eagle Models

CVO Screamin' Eagle 110c.i (1800cc)

The 2010 models are:

1. FLHTCUSE5: CVO S.E. Ultra Classic Electra Glide.
2. FLHXSE: CVO S.E. Street Glide.
3. FLSTSE: CVO S.E. Softail Convertible.
4. FXDFSE2: CVO S.E. Dyna Fat Bob.

The FLHTCUSE5: CVO S.E. Ultra Classic Electra Glide features:

Paint: H-D comes up with great names as usual.

- a) Riptide Blue with Titanium Dust.
- b) Scarlet Red Pearl with Dark Slate.
- c) Burnt Amber with Hot Citrus.

1. Color matched LED tour pack wraparound.
2. A pseudo air foil called an Air Wing Tour Pak luggage rack.
3. Adjustable passenger backrest with a perforated breathable leather insert.
4. Adjustable rider backrest with a perforated breathable leather insert.
5. Dual heated seat with a perforated breathable leather insert.
6. Roulette wheels.
7. Teardrop brake rotors.
8. Internally wired 1.25" handlebars.
9. A Tour pack 12-volt power outlet.
10. Tour pack and saddlebag lighting.
11. Tour pack bottom liner integrates a map, sunglass, and cell phone pouches.
12. The pegs, heated hand grips, mirrors, saddlebag latches, windshield trim, rider and passenger board inserts, are part of the Rumble Collection.
13. Fuel door and rear fender, medallions.
14. Dimple design insets for the air cleaner, CB pod and the tour pack lid along with mid-frame deflectors.

The FLHXSE: CVO S.E. Street Glide features:

Paint:

1. Tequila Sunrise with Pale Gold Leaf Graphics.
    - a) Candy Concord with Pale Gold Leaf Graphics.
    - b) Spiced Rum with Gold Leaf Graphics.
2. Color matched fairing skirt, fork covers (beer cans), and frame covers, rear saddlebag insert fascia, saddlebag latches, and LP rear light cover.
3. Gloss black inner fairing for all three paint schemes.
4. New mild-Ness style trimmed front fender.

5. New 1-piece extended saddlebags.
6. Mustache front engine crash guard with rubber pad.
7. New custom seat with a seat buckle and matching passenger seat strap.
8. Short tubular seat rail with French-stitched passenger backrest.
9. Contrast chrome 18" 7-spoke cast wheels.
10. Tires are Dunlop D407 130/70-18" front; 180/55-18" rear.
11. Directional 7-spoke floating brake disc rotors.
12. New hand-adjustable rear suspension that adjusts on the left side.
13. Internally wired 1.25" handlebars with chrome controls and braided front brake lines.
14. Miscellaneous items like new timing cover, front brake caliper, and air cleaner inserts; fairing trim, turn signal smoked lens, chrome oil cooler and gas cap covers, spun aluminum metal-faced gauges, 4" muffler end caps on 2-into-1-into-2 exhaust header pipes, and LED stop light and turn signals.

The FLSTSE: CVO S.E. Softail Convertible features:

Paint:

- a) Inferno Orange with Vivid Black.
- b) Crimson Red Sunglo with Autumn Haze.
- c) Abyss Blue with Sapphire.

1. The oil tank and frame inserts are color matched.
2. The new 2-piece tank console has painted accents.
3. New design clean uncluttered front fender.
4. New skirted wider rear fender to accommodate the new 18" wide 200mm rear tire with a 50mm super low profile.
5. The 18" chrome Stinger cast wheels feature a 3:50-18" front and a wide 6.00"-18" rear.
6. New 11.5" x .23" waved brake rotors.
7. All-chrome front forks.
8. New seat with a genuine buffalo insert.
9. New detachable passenger pillion seat with matching buffalo insert.
10. Qwik-detach wind deflector and smoked windshield.
11. Qwik-detach saddlebags.
12. Detachable passenger backrest and short seat rail.
13. Two-into-two staggered dual exhaust with slash cut mufflers.
14. New digital speedometer with a radial tachometer.
15. High flow intake breather with a rain-sock.
16. Internally wired 1.25" handlebars.
17. Rumble Collection grips, mirrors, floorboards, shifter peg, and brake pad with billet lever.
18. Lastly, there is a chrome headlight trim ring, rear fender accent strips, fender support covers with locking points for the saddlebags, and new rear lighting with integrated taillight, stoplight and turn signal functions.

The FXDFSE^2: CVO S.E. Dyna Fat Bob features:

1. Paint:
    a) Opel Blue with Hellfire flames.
    b) Cryptic Black with Hellfire flames.
    c) Satin Pewter with Sandstorm Grind. The frame and rear fork has a denim tinted clear coat.
2. A front lower frame spoiler.
3. Powdercoated and chrome-plated Fang wheels.
4. Black solid brake rotors.
5. Internally wired 1.25" handlebars.
6. Exhaust is 2-into-2.
7. Black header exhaust pipes.
8. The headlight housing, center tank console cover, fender strut cover, taillight cover, horn cover, timing cover, and derby cover are painted in a Midnight Pearl.
9. The pegs, grips, brake pedal rubber, battery cover trim, timing cover insert, derby cover insert, caliper inserts, intake emblem insert, the spoiler insert, and the gauge faces are part of the Diamond Black and Diamond Black Accents Collections.
10. The convertible to solo seat is distressed brown leather. The traditional problem with a solo convertible setup is that the passenger seat scuffs the paint and shows this when removed. H-D supplies a chrome and rubber underlay fender protector.
11. Then there are doodads like profiled custom mirrors, a slotted and shortened belt guard with a slotted rear pulley sprocket.

Conclusion

In 2010, Harley-Davidson is in survival mode returning to its core business. Any non-performing part of the business will discontinue. For example, if a particular model does not sell well, it will probably fall by the wayside. Harley-Davidson is streamlining all operations with a necessary vengeance.

CHAPTER XVI

2011 Model Changes

The 2011 H-D USA website (www.harleydavidson.com) offers "over 30 bikes starting at $7999". For two days I thought there were 30-different models starting at this bargain price but then I realized there were a total of 30-main models offered for 2011. The phraseology is nothing short of brilliant with the impression it leaves. Of course, it is the base model Sportster that begins at $\$7999.^{00}$ with prices accelerating with much torque after that especially with the four new CVO Screamin' Eagle offerings.

The Motor Company continues to aggressively market its motorcycles through financing incentives. The Great Recession has clipped its financing arm's wings making money scarce for loans to riders with little prospects of making repayment. However, H-D offers 1% (a nice play on words as H-D is not shy on borrowing the outlaw lifestyle) loans on selected models.

Many specifications reach back to 2009 for the touring models that include the first new FLT frame since 1980 and the 4-point engine-chassis suspension.

Certainly, the Dyna models brought much new innovation in past years such as the Cruise Drive 6-speed transmission combining with supercharged gear ratios on the mechanical front. Bold new styling was also a Dyna forté with fatter rear tires and forks. However, the Dyna is resting on past laurels to carry it through the last few years.

Much the same is true with the Softail lineup that dominated Big Twin popularity and production going back to the Evolution years. However, a shift in taste brought on by an aging population now looks more favorably on the touring models.

H-D wisely adds iPod technology to some models making a smooth move in hooking up with Apple.

More models are disappearing than new ones coming in as H-D streamlines their operations. The Motor Company relies heavily on paint to spruce new models. Certainly, H-D paint improves in quality and luster. Descriptive names evoke first-class imagery.

Fit Shop

Fit Shop is another great marketing move that allows potential and existing riders that are too short as in arms, legs, or hand grip; too small referred to as petit; or too big to have their new purchase *fit* to their particular body sizing.

I have been doing this for people for a few decades now as have many of other shops. This is a form of customizing to allow non-average sized people to fit on an average size Harley-Davidson.

This is standard fare marketed as a specialty service; legs too short to touch the ground, arms too short to reach handlebars comfortably, knees too high dwarfing the bike, and uncomfortable muscles or back from the seating arrangement juxtaposed with other components like the handlebars.

I have made special-fit handlebars; relocated or modified footpegs/floorboards; cut or extended fork springs and/or fork tubes; lowered or even extended rear forks (swingarms); extended and raked front ends or frames as well as making custom seats or narrowing and taking material out of stock seats all to accommodate different size riders.

As the aftermarket grew, many of the above machine shop modifications became available as pre-made parts like shorter shocks.

Now Harley-Davidson has marketed Fit Shop to do much the same thing except with Genuine bolt-on components installed in authorized dealerships. Where were they when I had a broken leg and rode my super high spring-mounted-seated 1959 Panhead replete with deadman's throttle, handshift with suicide clutch?

Parts Accessory Warranty

If buying eligible street legal Harley-Davidson parts and accessories that are installed by an authorized dealer for your new previously untitled Harley Davidson within 60 days of new motorcycle purchase they may be warranted for up to two years (remainder of the bike's 24-month manufacturer's warranty). This replaces the standard 90-day warranty for parts and accessories post-purchase over-the-counter warranty. Internet purchases will not receive this warranty offer.

Engine Changes

Parent Material Bearings

I have written extensively throughout this book, Volume I: *The Twin Cam* and also in Volume II: *Performancing the Twin Cam* about the use of parent material bearings. They have use:

1. In all year Twin Cam connecting rod big ends that rotate around the three 18-roller crank-pin-bearing sets. In the case of the big end connecting rod parent material bearings, the cast iron is heat treated for hardening.
2. The cam support plate also utilizes parent material bearings to support and guide the two outboard cam journals in the 2006 Dyna Glide as well as all 2007-to-present TC96, TC103, and CVO 110 models.
3. As the reader already knows, parent material bearings are not traditional roller, ball, or bushing bearings at all. They are precision holes that might be better referred to as races that support other rotating component parts. However, parent material bearings depend on the film strength of oil, sometimes only molecules thick to keep mating parts separated and lubricated.

Piston Wrist Pin Bushings Are No More

Piston wrist pin bushings located in the small ends of the connecting rods have always had use in Harley-Davidson engines. Piston wrist pins connect each piston to its respective connecting rod small end. Before 2011, the tubular wrist pins always rode in and were supported by the con rod wrist pin bushings. The wrist pins must semi-rotate in the wrist pin bushings to allow piston travel on their 45-degree trajectories.

This change to parent material bearings from actual wrist pin insert-bushings is a running change in late-2010 and early 2011 Twin Cam engines. I presume that the Motor Company wishes to use up inventory of connecting rod inventory and perhaps monitor the change before full commitment.

1. The upper taper of the connecting rod small end is now forged as opposed to being machined after casting. This is a cost savings measure as it eliminates a production step. The taper began utilization with the 2006 Dyna and all 2007-to-present Twin Cams to reduce reciprocating weight of the flywheels. This is an efficiency measure that reduces engine stress.
2. The parent material inner diameter (ID) dimension remains the same as with the precedent wrist pin bushing ID.
3. The parent material ID bore will now be honed to size. The installed wrist pin bushing required reaming (cutting) to size.
4. Replacement flywheel sets (crank) will use the parent material, wrist pin connecting rods. Therefore they will retrofit back to the 2006 Dyna Glide.

Cam Support Plate Pinion Shaft Bushing is History

The cam support plate bushing (25344-99) that has use from 1999 to 2010 in all Twin Cam engines now eliminates in favor of parent material in 2011. The functions of the bushing/parent material is twofold:

1. To lend support to the extending pinion shaft.
2. More importantly it feeds oil from the cam support plate into the pinion shaft for delivery to the crank pin, crank pin bearings, and parent material connecting rod big ends.

The inner diameter (ID) of the parent material remains the same as the support plate bushing. Furthermore, all service cam support plates will have parent material as opposed to a bushing. Therefore the new 2011 TC96, TC103, and CVO 110 cam support plates will retrofit back to the 2006 Dyna Glide.

Engine Case Pinion Bearing Updates

Harley has resolved a *walking* (movement) problem with the right engine case pinion shaft bearing (24605-07) known in Harleyese as the right main bearing retainer. To resolve this issue H-D has:

1. Changed the bearing installed depth in the right engine casing.
2. Reduced the outboard (timing chest side) right-engine-case casing material height surrounding the pinion bearing.
3. Introduced two retaining screws to lock in the pinion bearing, thus preventing any walking. The screws locate in the right engine casing (timing chest side) at the opposing 9-o'clock and 3-o'clock positions in the reduced casing material height surrounding the pinion bearing.
4. It is important *not* to use these screws as a tool to press the pinion bearing into place.
5. There is a spacer for the Kent Moore service tool to ensure the bearing installs to the specified height.
6 The early service tool requires a small chamfer to the outer diameter for clearance.

Engine Breather Apparatus Improvement

The breather apparatus locates one in each head, between the rocker arms. The new breather is a running change in late-2010 and early 2011 Twin Cam engines.

1. The bolts that attach the breather apparatus to the head casting through the lower rocker arm cover are now a different length than 1999 to 2010 bolts.
2. The new bolts also have a new torque specification. Consult your manual for installation instructions.
3. The breather assembly is simpler to save money; I am sure, and hopefully prove more efficient. The 1999 to 2010 aluminum components replace with a pressed-cover and a functional gasket that also separates oil from the gaseous mixture.
4. The sale of separate gaskets will no longer occur necessitating the purchase of a complete breather assembly. This certainly does not save the consumer money. The aftermarket as always will fill this void.
5. The 2011-to-present breather assembly will retrofit to earlier Twin Cam engines.

EFI Throttle Body Modifications

1. Touring FLT Models
    a) The throttle body is now die cast.
    b) It is more compact than the earlier fly-by-wire throttle body.
    c) There is now smaller throttle control motor (servomotor) housing.
    d) New calibrations are required.
    e) There are also new fuel lines.
    f) The 2011 throttle body will *not* retrofit to earlier models.
2. Softail and Dyna Glide Models
    a) There are two fuel vapor emission purge system ports at the front and top left of the throttle body.
    b) The rear one is gray in color and acts as an active purge for Softail models.
    c) The front one is black and acts as a passive purge for Dyna models.
    d) The two ports are capped for jurisdictions with less onerous emissions dictates.

Compensating Sprocket Assembly

For four years now, the compensator has not been able to deal adequately with TC96 and TC103 power pulses emanating from the engine. This noise has travelled the length of the powertrain and reverberated back to cause transmission gear clattering noise. The 2010 improvement in replacing the problematic 5th gear spur gears with helical ones has helped tremendously as has the IDS rubber mounted rear pulley's.

In 2011, all touring FLT models come equipped with the CVO 110, Trike, and the FCWC Screamin' Eagle compensator sprocket. This should be the final nail in a troublesome coffin.

Three O-ring Stator Plug

Another annoying problem for some models over the years is stator plug problems such as water leaking into the primary, oil leaking out past the stator plug from the primary, or the stator plug coming loose. There are now three O-ring seals:

1. Two blue ones (inner and middle) are oil seals. What the first does not stop, the second surely will.
2. The outer black O-ring is designed to keep water or other contaminants from going past the stator plug and into the primary chaincase oil bath.

Modified Clutch Hub Basket and Bearing

The clutch basket that holds the clutch plates changes to accommodate a new narrower bearing necessitating a relocation of the snap ring groove. The new assembly will retrofit as a unit.

2011 Overall Gear Ratios

All 2011 Twin Cam models utilize the primary gear ratio of 34/46 in place since the 2006 Dyna Glide. The engine sprocket has 34-teeth and the clutch hub sprocket utilizes 46-teeth.

Overall gear ratios show the number of engine revolutions required to turn the rear wheel one 360-degree turn. For example in 6th gear a 2011 Twin Cam:

Trike takes 3.157 engine revolutions to rotate the rear wheel once. The resulting torque is 3.157 times the engine's output.

1. Touring model takes 2.875 engine revolutions to rotate the rear wheel once. The resulting torque is 2.875 times the engine's output, which is the same as in 2010.
2. Dyna or Softail takes 2.790 engine revolutions to obtain the same goal of turning the rear wheel 360^0. The resulting torque is 2.790 times the engine's output, which is the same as in 2010.

Herein these comparisons, lies the reason for varying the overall gear ratios. It has everything to do with vehicle weight and the number of engine revolutions to turn the rear wheel once. The gear reductions (ratios) are engine torque multipliers.

Acceleration is all about torque, the twisting force generated by the turning engine flywheels. One way to accelerate more quickly is to multiply the torque at low speeds to help move the vehicle forward.

This is why the torque multipliers are much higher in 1st gear and progress downwards to 6th gear. Lower gears require more torque to get moving and less speed as they get moving.

- Furthermore, torque multipliers are less as the gears progress higher because less torque is required in favor of more speed.
- The motorcycle cannot have high torque and high speed at the same time but it can have a ratio of one to the other. Consequently, the overall ratio changes the torque multiplication from high torque-low speed progressively to less torque-high speed.

The reader will notice that all of the Trike ratios for each gear are higher than the Touring models, which are higher than the sportier model Twin Cams. Motorcycle weight is a huge factor in acceleration or power. The engine needs to generate more torque to move a heavier motorcycle.

2011 USA Overall Gear Ratios

Gear	Touring [1]	Trike [2]	FXD/Softail [3]
1st	9.593	10.537	9.311
2nd	6.650	7.303	6.454
3rd	4.938	5.425	4.793
4th	4.000	4.393	3.882
5th	3.407	3.742	3.307
6th	2.875	3.157	2.790

[1] Gear ratios for 2011 Touring models remain the same as 2010.The touring models are TC96 with the exception of the FLHTK with a TC103 powerplant. There is a new 2011 engine option called the PowerPak 103 that upgrades touring models in various countries to 103 cubic inches.

[2] The 2010 Trike gear ratios are 1st 9.878; 2nd 6.847; 3rd 5.086; 4th 4.118; 5th 3.508; 6th 2.960.

Both 2010 and 2011 trikes have a displacement of 103 cubic inches. The ratios change in 2011 for better low end torque because the transmission pulley reduces to 30-teeth (nubs) from 32-teeth.

[3] Gear ratios for 2011 Dyna Glide and Softail models remain the same as 2010.

Vehicle Identification Frame Label

In 2010 there are a few changes in interpreting the VIN (vehicle identification number) 17-digit code. Please see the preceding Chapter XV: *2010 Model Changes*, section *Vehicle Identification Numbers* for these VIN changes. The VIN number appears in two places on the frame:

1. The VIN is stamped on the frame near or on the frame neck (yoke).
2. The VIN also appears on a near-indestructible frame label affixed to the right frame downtube.

In 2011, there are two minor but significant changes to the frame label:

1. Bar codes like those found on most retail products are added to the frame label.
    a) The smaller bar code is the part number for the label itself.
    b) The larger bar code is the motorcycle VIN.

Touring Models

TC96: 1584cc and TC 103: 1690cc Rubbermount Engine/Chassis

The 2010 lineup includes the returning models, which are:

1. FLHTC Electra Glide Classic 1584cc.
2. FLHTCU Ultra Electra Glide Classic 1584cc.
3. FLHR Road King 1584cc.
4. FLHRC Road King Classic 1690cc.
5. FLHX Street Glide 1584cc.
6. FLTRX Road Glide Custom 1584cc.
7. FLHTK Electra Glide Ultra Limited 1690cc.

A new model FLTRU Road Glide Ultra features:

1. A PowerPak 103c.i. engine with 9.6:1 compression ratio.
2. ABS brakes.
3. King Tour-Pak with LED side running lights and a rear FLTRU medallion.
4. A 4-speaker audio system with a CB and intercom.
5. H-D smart security system.
6. An Ultra seat with a narrower front section for us guys with short legs and a better lower back support for us old guys.
7. Vented lowers.
8. Black gauges plus black and chrome medallions.
9. Straight mufflers.

PowerPak 103c.i. Option

USA FLHX Street Glide, FLTRX Road Glide Custom, and the FLHRC Road King Classic models are available with an optional 103c.i. engine that increases compression to 9.6:1 from the 96c.i. 9.2:1. The FLHTK Electra Glide Ultra Limited and the new FLTRU Road Glide Ultra come standard with the 103c.i. engine.

PowerPak 103 powertrain's will have a new oil cooler that incorporates a thermostat in the oil filter mount. It mounts off the front lower, horizontal frame adjunct that connects the two down tubes. There is an oil cooler cover and a frame cross plate as parts of the assembly.

Twin Cam 103c.i. models come with *103* designated transmission cover, derby cover, timing cover, and air cleaner cover inserts.

2011 USA Twin Cam Compression Ratios

Compression Ratio	Model	Displacement
9.2:1	FLHTC Electra Glide Classic	96c.i
9.2:1	FLHTCU Electra Glide Ultra	96c.i
9.2:1	FLHR Road King	96c.i
9.6:1 [1]	FLHRC Road King Classic	103c.i
9.2:1 [2]	FLHX Street Glide	96c.i
9.2:1 [2]	FLTRX Road Glide Custom	96c.i
9.6:1 [3]	FLHTK Electra Glide Ultra Limited	103c.i
9.6:1	FLTRU Road Glide Ultra	103c.i
9.2:1	FLSTC Heritage Softail Classic	96c.i
9.2:1	FLSTN Softail Deluxe	96c.i
9.2:1	FLSTF Fat Boy	96c.i
9.2:1	FLSTSB Softail Cross Bones	96c.i
9.2:1	FXCWC Custom Wide Softail Rocker Custom	96c.i
9.2:1	FLSTFB Fat Boy Lo	96c.i
9.2:1	FXDB Dyna Street Bob	96c.i
9.2:1	FXDC Dyna Super Glide Custom	96c.i
9.2:1	FXDF Dyna Fat Bob	96c.i
9.2:1	FXDWG Dyna Wide Glide	96c.i
9.7:1 [4]	FLHTCUG Tri Glide Ultra Classic Trike	103c.i
9.6:1	FLHXXX Street Glide Trike	103c.i
9.15:1 [5]	FLTRUSE S.E. Road Glide Ultra	110c.i
9.15:1 [5]	FLHTCUSE[6]: CVO S.E. Ultra Classic Electra Glide	110c.i
9.15:1 [5]	FLHXSE[2]: CVO S.E. Street Glide	110c.i
9.15:1 [5]	FLSTSE[2]: CVO S.E. Softail Convertible	110c.i

The FXSCTC Softail Custom and the FXD Dyna discontinue at the end of 2010. There is one new model for 2011, the 103c.i FLTRU Road Glide Ultra.

[1] The FLHRC Road King Classic increases to 103c.i. with a 9.6:1 compression ratio in 2011 from 96c.i. and 9.2:1 compression ratio in 2010.

[2] The DOM (Domestic USA) models have the PowerPak 103 option that will increase displacement to 103c.i. and compression to 9.6:1 from the 96c.i. base, which has a compression ratio of 9.2:1.

[3] The 103c.i. FLHTK Electra Glide Ultra Limited compression reduces to a still very healthy 9.6:1 from the introductory 2010 year of 9.7:1.

[4] The FLHTCUG Tri Glide Ultra Classic Trike increases compression to 9.7:1 in 2011 from 9.6:1 in 2006.

[5] It is remarkable that the biggest and therefore, most powerful engine, the CVO 110c.i has the lowest compression ratio. The three main ways to augment engine power is increasing air flow with head work, swept cylinder volume (displacement or cubic inches), and/or the pressure in the cylinders known as compression. The CVO has to lessen heat that causes engine-killing detonation. In order to meet emissions controls, the Stoichiometric air-fuel-ratio is used in the closed loop EFI to create the heat to burn as much harmful emissions as possible. EPA is non-negotiable on allowable emissions. Therefore, the only other way outside of complete engine re-design to lessen heat is to reduce the compression-pressure in the cylinders. The 103c.i models with either 9.6:1 or 9.7:1 compression will give the 110 cubic inch models with an anemic 9.15:1 compression ratio a run for its money.

Optional PowerPak 103c.i. Availability by Country

	USA	California	Canada	England	Brazil	Australia	Japan	HDI [1]
FLHTC					yes			yes
FLHTCU					yes	yes	yes	yes
FLHR						yes		yes
FLHRC	yes	yes	yes		yes	yes		yes
FLHX	yes	yes	yes	yes	no	yes		yes
FLTRX	yes	yes	yes					yes

[1] HDI is the acronym for H-D International. HDI motorcycle supply may confuse with individual countries that are normally serviced by HDI or vice versa. Consult with H-D websites for various countries for clarification.

Touring Rubbermount Pivot Shaft Assembly Change

H-D has had ongoing problems with the rubbermount pivot shaft assembly since 1980. Over the years, there have been many changes and upgrades. The pivot shaft assembly works well and always has except for removal. They have a tendency to seize as moisture builds up, rusts metal parts and pretty much welds them together over a period of a few years service. There is a new pivot shaft assembly for touring models in 2011:

1. The assembly connects the rear fork to the frame on either side and travels through the rear of the transmission in the center section of the connection to tie all three components together as always.
2. There are two new outer pivot shaft bolts.
3. The bolts fit through a new spacer that fits through an isolator (rubber mount) on either end of the assembly.
4. The new pivot shaft extends through the transmission housing with an outer spacer, bearing, and an inner spacer on either side of the casing.
5. Torque the new pivot shaft bolts to 55 ft-lbs to 65 ft-lbs (74.5 Nm to 88.1 Nm).

Miscellaneous Touring

1. There is a new 2-into-1-into-2 exhaust system for the FLHX Street Glide and the FLTRX Road Glide Custom.
2. The FLHX has nice new floorboards.
3. The FLHTK Electra Glide Ultra Limited loses its front fender bumpers.
4. Molex connectors replace the Deutsch ones to service the rear audio speakers where fitted.

Trikes: 103c.i (1690cc)

The FLHTCUG Tri Glide Ultra Classic introduced in 2009 and the FLHXXX Street Glide Trike introduced in 2010 continue into 2011.

Electric Reverse Now Standard

The formerly optional electric reverse is now standard on 2011 trikes. A new Reverse Control Module relocates to under the right side cover.

New 30-tooth Transmission Pulley

The 2010 Trike gear ratios are 1st 9.878; 2nd 6.847; 3rd 5.086; 4th 4.118; 5th 3.508; 6th 2.960.
The 2011 ratios are 1st 10.537; 2nd 7.303; 3rd 5.425; 4th 4.393; 5th 3.742; 6th 3.157.

Both 2010 and 2011 trikes have a displacement of 103 cubic inches. The ratios change in 2011 for better low end torque. This achieves because the transmission pulley reduces to 30-teeth (nubs) from 32-teeth.

Exhaust Mounting Improves

The exhaust mounting isolator (rubber mount) is necessary on all rubbermount touring models is necessary because the exhaust system connects with the rubber mounted engine while the muffler brackets rigid mount to the frame. The Trikes have had some mounting issues in 2009 and 2010. Therefore, the exhaust mount isolator for each muffler is now longer for improved holding.

Brakes and Tires

1. Increased surface brake pad area.
2. Different friction material.
3. Rear brake discs are hardened (quenched and tempered).
4. The brakes will retrofit to 2009 and 2010 Trikes.
5. I don't believe this one. Simple omissions lead to bigger problems like vibration and handling issues. It is necessary to know the lightest spot on a tire for proper tire mounting and thus balancing. H-D motorcycle tires, whether OEM or aftermarket have had a balance dot (usually a small painted yellow dot) indicating the lightest spot on the sidewall. Apparently 2009 and 2010 trike tires do not have this dot. The dot becomes standard in 2011.

Trike Body Changes

There is a new body including the hopefully no longer perennial leaking trunk door with side covers and fenders for 2011. There is a closer integrated fill gap between the seat and the trunk body. There is also:

- More trunk door clearance since the radius in the door recess reduces.
- New trunk door lanyard mounts with a shoulder bolt are now moulded into main body/trunk door.
- New trunk door seal profile with a trunk door rib for sealing attempts to deal with those pesky, chronic leaks. Lehman Trikes whose initial designs were used for the H-D Trikes have had problems forever with leaking trunk doors. I was a Lehman dealer for many years; the two main customer complaints were front wheel shimmy and leaking trunks.
- The trunk door has molded in stiffening ribs to reduce flex that may contribute to water intrusion.
- The pressed-in fender mounting inserts are blind (can't see them).
- The fenders mount using an excellent and new SEM (www.sem.ws) fastener.
- The fenders use an integrated mounting tab with a metal center bushing for improved reliability.
- The tail light pocket in each fender has a redesign.
- A trunk door locking upgrade with a single latch system.
- New connector for the trunk light necessitating a new wiring harness section.
- Wire routing locations replace the former plastic wire ties.

Miscellaneous

- There is a new service procedure for Trike starter motors. Please consult your manual.
- The upper fork bracket (crown) modifies for improved steering lock engagement.

Softail Models

Softail TC96B: 96c.i (1584cc) Counterbalanced Engine/Rigid Chassis

The 2011 lineup includes the returning models, which are:

1. FLSTC Heritage Softail Classic.
2. FLSTN Softail Deluxe.
3. FLSTF Fat Boy.
4. FLSTSB Softail Cross Bones.
5. FXCWC Custom Wide Softail Rocker Custom (Rocker C).
6. FLSTFB Fat Boy Lo

One Softail model discontinues after 2010: FXSTC Softail Custom.

What's New?

The reader may want to reference Chapter XI: *Twin Cam Electrics*, section *Electrical Future Begins in 2011* for a look at the future in present day. The Softail is the new guinea pig for the Harley-Davidson Local Area Network (HDLAN) and the Controller Area Network (CAN) that manages and coordinates various modules, eliminates some, reduces wiring gauge, wiring number, wiring harness bulk as well as most fuses and relays. This is great stuff; a little intimidating at first but will eliminate many potential problems. This system will certainly spread to the whole H-D lineup.

There aren't many other changes except for paint to the Softail lineup but they include:

- a) ABS Brakes (Anti-locking Braking System) as an option.
- b) Separate ABS hydraulic control units (HCU) for front and rear brakes.
- c) System control is via a single ECU (electronic control unit).
- d) ABS models have encoded wheel bearings on the sensor side of each wheel that read if tire traction is lost or regained by changes in wheel speed.
- e) The frame, rear fork, and splash guard modify to accommodate the new mounting requirements and routing of ABS components.

1. The evaporative charcoal canister location on California (CAL) and some HDI (H-D International) markets must move to give room for the ABS HCU. The canister repositions behind the inner primary chaincase. The evaporative line now controls by a solenoid purge valve assembly. This necessitates a gas tank redesign to reshape for this change. This will all be coming for the rest of the USA and other countries soon enough. As I say many times; emissions controls drive Harley-Davidson design.
2. Diagnostics with Digital Technician II is covered in Chapter XI: *Twin Cam Electrics* in section *Digital Technician II: Modern Diagnostics.*
3. All midyear Softail production except the FLSTSB Cross Bones have a brake pad change with a metal shim backing. The pads identify with a white paint blotch. Remarkably, the 2011 bikes have only been released and there is this MY production change planned.

Dyna Models

The Dyna incorporates the parent material in the connecting rod small ends and the pinion shaft hole in the cam support plate as well as the pinion bearing retention and the clutch hub/bearing changes. Other than this, there are no major changes except for new paint. The FXD Dyna drops out of sight as the Dyna Glide lineup trims down and rests on past laurels.

Dyna TC96: 96c.i (1584cc) Rubbermount Engine/Chassis

The 2011 lineup includes the returning models, which are:

1. FXDB Dyna Street Bob.
2. FXDC Dyna Super Glide Custom.
3. FXDF Dyna Fat Bob.
4. FXDWG Dyna Wide Glide.

CVO Screamin' Eagle Models

CVO Screamin' Eagle 110c.i (1800cc)

The four 2011 models continue with three updated 2010 versions with one completely new offering, the FLTRUSE: CVO S.E. Road Glide Ultra. All CVO engines are granite and chrome. I guess granite is the new descriptive black.

1. FLHTCUSE^6: CVO S.E. Ultra Classic Electra Glide.
2. FLHXSE^2: CVO S.E. Street Glide.
3. FLSTSE^2: CVO S.E. Softail Convertible.
4. FLTRUSE: CVO S.E. Road Glide Ultra.

The: FLHTCUSE^6 CVO S.E. Ultra Classic Electra Glide features:

Paint: H-D usually has three or four paint choices but only one for this CVO.

   a) Black Ember & Rio Red/Flame Graphics.

1. North American models feature SAE J1349 measured 115 ft-lbs (156 Nm) torque @ 4000 rpm at the engine.
2. Road Tech zumo 660 navigation.
3. New audio system navigation interface.
4. The contrast chrome Roulette cast wheels feature a 3:00-17" front and a wide 5.00"-16" rear.
5. Tires are front D408 130/80-17" and rear D407 180/65-16".
6. Oil cooler with a chrome cover.
7. Billet chrome muffler end caps.
8. Adjustable rider backrest with leather inserts.
9. Hammock style reshaped rider seat suspension.
10. Passenger backrest has an adjustable lumbar support (gotta keep the boss happy) with leather inserts also.
11. Passenger seat spring-board suspension.
12. Dual control heated seat, again with leather inserts.
13. Customer care package that includes a tool kit, micro fiber detailing cloth (yabbadabbado), and a jiffy stand (sidestand) coaster so we don't sink into hot asphalt or whatever.
14. Teardrop brake rotors.
15. Internally wired 1.25" handlebars.
16. A Tour pack 12-volt power outlet.
17. Tour pack and saddlebag lighting.
18. Tour pack bottom liner integrates a map, sunglass, and cell phone pouches.
19. The pegs, heated hand grips, mirrors, saddlebag latches, windshield trim, rider and passenger board inserts, are part of the Rumble Collection.
20. Fuel door and rear fender, medallions.
21. Dimple design insets for the air cleaner, CB pod and the tour pack lid along with mid-frame deflectors.

The FLHXSE^2: CVO S.E. Street Glide features:

Paint: H-D comes up with great names as usual.

- a) Kryptonite/Black Diamond.
- b) Black Diamond/Inferno Orange.
- c) Autumn Haze/Antique Gumstock.
- d) Black Diamond/Crimson Tag Graphics

1. North American models feature SAE J1349 measured 115 ft-lbs (156 Nm) torque @ 4000 rpm at the engine.
2. Contrast chrome 18" 7-spoke 5.00" contrast chrome Agitator cast rear wheel.
3. Tire is Dunlop D407 180/55-18" rear.
4. Contrast chrome 19" 7-spoke 3.50" contrast chrome Agitator cast front wheel.
5. Tire is Dunlop D408 130605-19" front.
6. Agitator floating disc brakes with chrome center.
7. Extended, full depth saddlebags…nice touch.
8. Side fill gas tank with flush caps…another nice touch.
9. Six speaker, high output audio system with 100 watts per channel.
10. Audio interface with an iPod nano.
11. An 8GB iPod nano is supplied with the motorcycle.
12. The right saddlebag contains a connector and storage pouch for the iPod.
13. The iPod charges while the ignition switch is in the IGNITION or ACCESSORY position.
14. The radio display screen will change to an iPod screen when in use.
15. Handlebar controls, audio system soft keys, and passenger audio controls (if available) allows control and navigation of the iPod.
16. Harley-Davidson has certified the iPod nano for motorcycle usage.
    - a) The iPod touch can be used but H-D has not certified its use. The rider must start the iPod music application before using the iPod touch.
    - b) The iPhone can be used but H-D has not certified its use. The rider must start the iPhone music and then change the setting to *airplane mode* in order to prevent the iPhone from ringing through the speakers.
    - c) Do not use an iPod classic as damage to the iPod is possible.
    - d) The iPod shuffle will not work.
    - e) If using a device other than the recommended iPod nano, a warning message will display if the audio system recognizes it. If using this recognized device, press and hold the OK soft key to clear the warning message.
    - f) Devices that don't have an iPod dock interface will not be compatible and cannot connect with the audio system.
    - g) H-D does not recommend hard-drive based device usage because the motorcycle's vibration may internally damage the piece of equipment.
17. Low profile seat with snake skin inserts.
18. Matching low profile center console.
19. Hand adjustable rear suspension.
20. LED turn-tail-stop rear lighting.
21. Customer care package that includes a tool kit, micro fiber detailing cloth and a jiffy stand (sidestand) coaster.

The FLSTSE²: CVO S.E. Softail Convertible features:

Paint:

   a) Scarlet Red Pearl & Dark Slate Pearl with Metal Grind Graphics.
   b) Midnight Sky & Candy Cobalt with Blue Ice Graphics.
   c) Maple Metallic Roman Gold with Burnished Copper Graphics.

1. North American models feature SAE J1349 measured 110 ft-lbs (149 Nm) torque @ 3000 rpm at the engine. Softail counterbalancers cause the parasitic power loss when compared to the rubber mount models.
2. ABS braking system.
3. Keyless ignition system.
   a) Take the security Fob with you when leaving your motorcycle parked (ignition OFF) to prevent theft or someone playing with your machine.
   b) Ignition mode: set handlebar OFF/RUN switch to RUN with security Fob close by. This operates the lights and instruments and allows starting. To turn engine off, set the OFF/RUN switch to OFF. If leaving the bike running, it will continue to run even with the Fob beyond range. The speedometer displaying a NO FOB message will remind a rider if he/she takes off without the Fob.
   c) Accessory mode: If wanting to listen to tunes with the bike off, hold the TRIP switch with the Fob close by. This powers the instruments and the accessory circuit but not the battery draining headlight or turn signal lamps. The bike will protect the rider by turning accessory mode off after 2-hours use to leave enough juice for starting. If this occurs, press the TRIP switch again for normal operation.
   d) Disarming security by manually entering the PIN. The odometer display will guide the rider through each step. Sitting on the motorcycle in the upright position, depress both turn signal switches until the LCD screen displays *Enter PIN*. Press and release the left turn signal switch. The LCD will flash the numeral 1. Continue pressing the turn signal button to increase the numeral incrementally. Press the right signal button to enter the number displayed and the LCD will automatically move to the next numeral/digit. Press the left button to select the next numeral/digit and begin the process over again. There are 5-numeral/digits (PIN) to enter. Now press the right signal button to disarm the security.
4. Electronic (fly-by-wire) throttle control.
5. Cruise control.
6. The 18" chrome Stinger cast wheels feature a 3:50-18" front and a wide 6.00"-18" rear.
7. Stinger floating disc brake rotors.
8. Tires are front D407 130/70-18" and rear D407 200/50-18".
9. Full coverage fenders, front and back.
10. The leather, locking, sealing saddlebags; color-matched fairing-windshield, passenger pillion, and passenger backrest are detachable.
11. The saddlebag locks match with the fork steering lock.
12. There is a fairing mounted audio amplifier with 20 watts per channel.
13. There is also an 8GB iPod nano.
14. Digital speedometer with an analog tachometer.
15. Internally wired mini-ape hanger 1 ¼" handlebars
16. Lowered suspension.

17. Extended jiffy (sidestand) stand.
18. Integrated turn-stop-taillight signals.
19. Alligator style (protect the environment) inserts in the saddlebags and the seat.

The FLTRUSE: CVO S.E. Road Glide Ultra features:

Paint:

1. Rio Red & Black Ember/Quartzite Graphics.
    a) Charcoal Slate & Black Twilight/Quartzite Graphics.
    b) Frosted Ivory & Vintage Gold/Quartzite Graphics.
2. North American models feature SAE J1349 measured 115 ft-lbs (156Nm) torque @ 4000 rpm at the engine.
3. BOOM! Audio with front and rear speakers and a tuned amplifier.
4. Road Tech zumo 660 navigation.
5. New audio system navigation interface.
6. Audio interface with an iPod nano.
7. An 8GB iPod nano is supplied with the motorcycle.
8. The right saddlebag contains a connector and storage pouch for the iPod.
9. The iPod charges while the ignition switch is in the IGNITION or ACCESSORY position.
10. The radio display screen will change to an iPod screen when in use.
11. Handlebar controls, audio system soft keys, and passenger audio controls (if available) allows control and navigation of the iPod.
12. Harley-Davidson has certified the iPod nano for motorcycle usage.
    a) The iPod touch can be used but H-D has not certified its use. The rider must start the iPod music application before using the iPod touch.
    b) The iPhone can be used but H-D has not certified its use. The rider must start the iPhone music and then change the setting to *airplane mode* in order to prevent the iPhone from ringing through the speakers.
    c) Do not use an iPod classic as damage to the iPod is possible.
    d) The iPod shuffle will not work.
    e) If using a device other than the recommended iPod nano, a warning message will display if the audio system recognizes it. If using this recognized device, press and hold the OK soft key to clear the warning message.
    f) Devices that don't have an iPod dock interface will not be compatible and cannot connect with the audio system.
    g) H-D does not recommend hard-drive based device usage because the motorcycle's vibration may internally damage the piece of equipment.
13. Pebble textured adjustable rider backrest with leather inserts.
14. Pebble textured hammock style reshaped rider seat suspension.
15. Passenger backrest has an adjustable lumbar support with leather inserts also. Ultra Road Glide monogram with pebbled texture
16. Passenger seat spring-board suspension.
17. Mirror chrome 18" 7-spoke 5.00" Agitator cast rear wheel.
18. Tire is Dunlop D407 180/55-18" rear.
19. Mirror chrome 18" 7-spoke 3.50" Agitator cast front wheel.
20. Tire is Dunlop D408 130/70-18" front.
21. Agitator floating disc brakes with chrome center.

22. Reduced angle Road Glide 16" softly smoked windshield.
23. Road Glide wind deflectors between the frame and the fairing.
24. Inner fairing lined storage box.
25. Oil cooler with a chrome cover.
26. Billet chrome muffler end caps.
27. Internally wired 1" handlebar
28. Diamond cut identifier inserts.
29. Customer care package that includes a tool kit, micro fiber detailing cloth and a jiffy stand (sidestand) coaster.

Conclusion

In 2011, Harley-Davidson continues streamlining operations and models. Yes there are still many upgrades and improvements but not as many as usual. Many are cost saving like the progression towards parent material bearings from former roller or ball bearings and bushings. Others, like some of the 2011 wheels are the same as those used in the previous year. Look no further than the Agitator and Roulette wheels in the CVO lineup. However, the paint is exemplary as usual and hides any repetition except from the most discerning eye.

CHAPTER XVII

Why is the Twin Cam Superior?

The Twin Cam design takes the air-cooled Harley-Davidson Big Twin to a new level with its superior engineering, metallurgy, casting, machining, fitment, and sophistication relative to what went before.

The post World War II baby boom demographics is the primary reason for Harley-Davidson's growth explosion beginning in the nineteen-eighties continuing up until 2007. However, the demographics also wanted quality with their cup of nostalgia as they attempted to find the Fountain of Youth. The Harley-Davidson boom could not have occurred without a new invigorating product.

Best Oil Pump to Date

The internally, pinion shaft mounted oil pump is an old idea, which Harley-Davidson utilized a long, long time ago. In those days, oil pump failure occurred because of inadequately filtered oil. This is of no concern now with the best filtration system ever.

High Pressure and High Volume Geroter Use

The Twin Cam depends on internal oil pump geroters that cover oil intake and oil outtake ports while putting trapped oil in a decreasing-size space to create higher volume and higher pressure than the moderate volume and moderate pressure of predecessor gear-driven pumps. Greater pressure is created because oil will not compress like air will.

Oil Pressure

Twin Cam oil pressure is the highest in the history of the air-cooled Big Twin Harley-Davidson. Therefore oil is delivered to ensure every nook and cranny gets its fair share of lubrication, cooling, particulate removal, and of course sealing.

TC88, TC96, TC103, and CVO 110 Twin Cam oil pressure should range between 30psi to 38psi (207kN/m^2 to 262kN/m^2) at 2000 rpm/engine at operating temperatures, which is 230^0 F (110^0 C). Compare this with the Evolution range of 12psi to 35psi (83kN/m^2 to 241kN/m^2) @ 2000 rpm/engine at operating temperatures.

Oil Filtration

Superior oil filtration from a 1999 to 2006 10-micron (10-millionsth of a meter) filter and the 2007-to-present 5-micron (5-millionsth of a meter) filter competently protects all internal engine parts including the internal alloy oil pump housing from dirty, particulate laden oil. Oil filters on the feed side, going into the engine not on the return side as in previous models.

Oil-sealing

Engine Covers *No* Longer Support Moving Engine Components

All engine covers like the timing or gearcase cover, the split two-piece rocker wafers, and the guide block covers are just that, covers. No more do covers act as load-bearing supports for other engine parts. This innovation helps dampen noise and reduces possible oil leaks.

Previous engine covers did double duty as support mechanisms for component engine parts like the outboard-cam-journal, pinion shaft end support and oil feed, rocker arms, and hydraulic lifter tappets. Their movement whether from out-of-true fitment or creating vibrational forces had a tendency to loosen covers and thus create oil leaks.

Twin Cam Gaskets

Service departments have lost a major source of income in replacing defective or weeping gaskets. Example the rocker gaskets; rubber coating with an embossed steel core provides uniform pressure throughout. The embossing is a ridge, if you will; something like the silicone beads now found on high-quality aftermarket gaskets, except it is a coated metal. This metal embossing goes around the bolt-holes, as well as the gasket surface to provide a uniform pressure seal on quality machined surfaces. No longer should Harley mark its spot.

Component Tie-down Improves

More tie-down fasteners support the gasketing and seal functions. For example, the Twin Cam timing cover and primary chaincase clutch inspection derby both have an increase in fasteners.

Cover Design Improvements

There are two rocker wafers on the Twin Cam engine rather than the three found on the Evolution. Thus there is a 33% less chance of a leak even before looking at the mating cover design, which also thwarts leakage. Combine this with the superior gasketing and we have a leak-proof engine.

Superior Cooling

The Twin Cam heads and cylinders use 60% more finning area to dissipate combustion and frictional generated heat. This is a big deal on an air-cooled engine. The Evolution and previous H-D engines contained heat within. The Twin Cam expels heat to dissipate into the surrounding air. This can be a little uncomfortable for the rider but salvages the engine internals.

The 1 ⅝"-diameter crank pin has a feature that few know about. The crank pin is not solid steel but is in reality is a very strong and supportive hollow tube. Each end of the crank pin plugs with steel caps that are pressed into the hollow ends, thereby creating a sealed internal reservoir that absorbs heat from the heart of the engine.

Furthermore, there are three oiling holes inside the crank pin, one each to lubricate each set of bearings. This provides exceptional lubricity relative to the single oil-hole crankpins in every previous Big Twin engine. More oil in more places allows for more heat removal.

Friction Reduction

Hypereutectic Pistons

Hypoeutectic, Eutectic and Hypereutectic refers to piston-manufacturing techniques and alloy composition with silicon content a major determinant of piston type. Hypereutectic is a cast piston with greater than 12% silicon content. If the piston has 17% silicon content, 12% dissolves uniformly throughout the alloy while the remaining 5% crystallizes as primary insulating silicon crystals, which resist cracking in the piston crown area where temperatures are most severe. The primary crystallization prevents heat transfer to the more vulnerable piston skirt thrust areas, allowing them to run cooler.

Hypereutectic pistons used in all Twin Cams are the strongest of the three types. These superlative pistons have the smallest expansion rates of any other piston types used in Big Twins and Sportsters. Hypereutectic pistons have very close fitment to cylinder wall. They are also most resistant to piston-to-wall scuffing and are least likely to suffer a seizure situation. Twin Cam hypereutectic pistons are extremely durable.

Teflon-coated Piston Skirts

The piston skirt thrust surfaces, fore and aft, have a Teflon-like coating from the ring lands down. This durable and slippery coating reduces friction and thus heat generation. It also assists in break-in and in combination with hypereutectic piston composition allows for the ultra-thin tolerance between piston thrust surface and cylinder wall.

Copper-coated bottom end Roller Cages

The copper coating helps with break-in procedures, promotes durability, and offers easy wear-spot identification. The slippery coating reduces friction and thus heat.

Captured Fit Bearings in Cages

Capture is an engineering term to describe the type of bearing cage that gives maximum support to each of the eighteen bearings per cage. This type of bearing cage prevents the bearings from rolling sideways off-square with their path and thereby creating frictional drag as opposed to rolling true and straight as designed. The Twin Cam bearings *pop* in and out of their race and will not fall out via gravity. Hence the descriptive term captured.

Brute Strength

Strength and rigidity that offers superior component support as well as a reduction in torsional flexibility is an ongoing theme with the Twin Cam.

The transmission housing and engine casings now become as one eliminating flex. The primary chaincase still lends support but is no longer solely saddled with this responsibility.

1. Cylinders are shorter with a thicker liner to unyieldingly guide the pistons surely and consistently in their cylinder bores. The Twin Cam cylinder sleeves are .247" thick compared to the Evolution at .173".
2. There are 3-more bottom end rollers than the Evolution…3-sets of 18-rollers as opposed to 3-sets of 17-rollers in the Evolution.
3. The bearings are the same diameter but longer than their Evolution or Shovelhead counterparts. The male bearings are ⅜"-long and half that in diameter while the center male rollers are twice the length at ¾"-long, the diameter being the same at $^{3}/_{16}$".
4. The connecting rods *look* similar, just bigger with more muscle everywhere.
5. Wrist pins and bushings are the largest ever used on a Harley-Davidson offering extra support and balance
6. The Twin Cam utilizes the biggest, strongest crank pin yet. It also offers superior lubrication to bottom end crank components via three oiling holes as opposed to the previous single oiling hole. The size of the straight, three-hole oiling crank pin is impressive. Its outside diameter is a full .420" bigger than the diameter of the now skinny old single oiling-hole crank pin used in the Evo.
7. The pinion shaft is forged as part of the right-side flywheel. The Twin Cam pinion shaft is .400" thicker than its Evolution counterpart at the pinion bearing location.
8. The humungous pinion shaft roller bearing is about 3 ½" in diameter, it is approximately double the size of that of the relatively skinny needle roller bearing utilized in the Evolution engine.
9. I could continue giving examples of strength and rigidity with the Twin Cam engine and motorcycle but I think the point has been convincingly illustrated.

Twin Cam Engine Cases

The Twin Cam engine cases are the best ever. They are high-pressure die cast aluminum with 360-specially formulated proprietary alloys. These beauties promote rigidity, strength, and durability as the framework for what is inside and on top. I predict that engine casing oil leaks and/or cracking is now a thing of the past.

A major problem when manufacturing engine casings is how many times clamping them is required for a machining process. Every time this occurs the alloy deforms, which can cause machining distortions as the alloy bounces back to its former shape before clamping. Less clamping means a superior product. Evolution cases require clamping 32-times before fully machined. The Twin Cam manufacturing process reduces this to 5-times.

The Twin Cam Head: Evolution Continues

The Evolution head finally dispensed with the inefficient hemi-heads and round dome piston crowns used on all three previous overhead valve engines, the Knucklehead, Panhead, and Shovelhead from 1936 to 1985. The two main changes that led to an increase in gas mileage, speed, and emissions controls are the use of a squish band in combination with a flat-topped piston and decreasing the valve angles.

Squish Bands

The squish band is a feature found in Harley engines from 1984 on with the advent of the Big Twin Evolution engine. Specifically, the *single-sided* Evolution squish band involves a radical change to the combustion chamber shape from previous hemi-head configurations. The hemi-head was the leading engine technology of the time. However, it depends on solely increasing cubic inches for more power not more efficiency.

The squish band chamber in combination with a flat top piston was a tremendous move forward for the Factory. I would even venture to say that it is probably the most important design change of many important innovations in decades. More importantly, the Twin Cam combustion chamber shape became the basis for the even more sophisticated *wraparound* squish shape for the Twin Cam 88 that continues with improvements in the TC96, TC103 and CVO 110 engines. These changes that most never notice include superior porting of the intake tracts for increased flow.

Turbulence Mixes the Air and Fuel

In short, the bathtub-shape Twin Cam combustion chamber produces more horsepower with less gas. Furthermore this extra horsepower generates with fewer emissions. This occurs because a higher percentage of the air/gas mixture burns.

Turbulence generated by the air and gas squishing into a smaller combustion chamber mixes the molecules of this mixture better than in any previous Harley. The superior mix leads to a higher percentage of burn.

Changing the Valve Angle

Another huge improvement for the Evolution head that continues on with the Twin Cam over the predecessor hemi-head engines is a substantial reduction in valve and valve guide angles.

The semi-rotational rocker arm pad pushes the valve open when directed by the cam lobe via the valve train. It opens the valve by rubbing across while pushing down the top of the valve stem. This counterproductive force pushes the valve against its valve guide creating friction and thus a negative force. The greater the angle, the more the negative force called side-loading exists. There are two main problems:

1. Excessive wear of the valve stem and valve guide.
2. Loss of frictional horsepower from one part working against another. Now, there is not much negative loss but the goal is to have a neutral or positive gain.

Evolution and Twin Cam motorcycles benefit greatly from side loading reduction. This allows for higher cam lifts. The valves can now open further into the combustion chambers due to less side-loading allowing in more air and gas as well as reducing valve guide wear and frictional loss of horsepower.

Tulip Valve Heads

As the TC88 years progress, the upside portion of the valve heads lose their flattened shape and become Tuliped with an angular swirl contour that promotes superior flow of the air-fuel mixture into the combustion chamber.

Rocker Arm Ratios

Moreover, rocker arm ratios increase to 1.625 in Evolution and Twin Cam engines from the Shovelhead 1.420 ratio allowing much higher valve lifts using the same cam lobe lift. Suppose we have a .290" *cam lobe lift* cam in both a Shovelhead and a Twin Cam; the *valve lift* in the Shovel will be (1.420 x .274" = .390") .390" valve lift. The valve lift in the Twin Cam with the same .274" cam lobe lift will be (1.625 x .274" = .445") .445" valve lift. The new rocker arm ratio increases the valve lift by a full .055".

Of course, the Twin Cam engine never had a cam lobe with such anemic lift as that of the Shovelhead. The reasons for this safe, reliable increase allowing more air and fuel flow is a decrease in valve angles and a higher rocker arm ratio.

Much-improved manufacturing techniques, newer technology and better quality materials further contribute favorably to an increase in compression ratios and higher lift cams. *Certainly, radical cam lobe lift and duration figures in a Shovelhead become very normal and safe in the Twin Cam.* In short, for an antiquated but beloved engine, we have huge changes and improvements that allow for radicalization of previous standards as they now become normal and safe.

Compression Increases for More Power

Superior metallurgy, a much-improved engine management system that includes reliable EFI and above all else, a flat-topped piston buttressing against the most sophisticated combustion chamber design to date allows for a safe increase in compression. Increases in compression will boost power dramatically.

Less Valve Train Weight

In 1999, the Twin Cam continued to use the Evolution valve springs instituted in 1984. These dual cylindrical shaped valve springs, one inside the other hold each valve closed on early Twin Cams up until 2003 and early 2004.

A single beehive shaped valve spring operates the closing of each valve from circa 2004 on. Thus, this single valve spring bridges both late TC88 engines as well as the TC96, TC103, and CVO 110 engines. The valves used with the beehive springs also have thinner valve stems reducing valve weight and thus valve train mass. Anytime valve train weight reduces, two beneficial results emerge:

The engine can rev higher since there is less mass to move up and down.

1. Secondly, a lower seat pressure valve spring will perform intended functions since there is less weight to impede the valve's return to its seat.
2. This reduces valve seat slam and thus wear from the returning valve.

Rapid acceleration and high rpm riding can create harmonics where the valve spring-coil begins to behave erratically instead of applying consistent unwavering pressure to return to the closed position. If a valve spring (set) has even dimensions and pressure capability throughout its length, harmonics can and often will occur. To counter valve spring harmonics on dual spring sets, the inner spring normally counter winds to the outer to combat fibrillation. The different sizes of inner and outer also combat this untoward spring movement away from designed compression and extension under duress of performance riding and/or cam design. The springs may also progressively wind, whereby coils are closer together at one end than on the other spring to prevent harmonics from impeding intended travel and function. The single beehive spring progressively changes shape from narrow on the top valve collar to wide on the bottom lower collar. The changing diameters of the coils have progressively changing physical properties that battle fibrillation from gaining a foothold and expanding their counter-surging characteristics.

Valve Train Angularity Problem Resolved

Valve train angularity is different than valve angle. The centrally located Evolution camshaft with 4-inline cam lobes one for each valve presented an angularity problem.

Pushrod valve-train angularity is a design impediment of yesteryear engines from 1936 to 1999 that were intolerant of low duration, high lift cam profiles. These engines needed longer duration cam lobes to ensure the lifters could follow them without flying off in a momentum, inertial driven frenzy promoting valve float, another great engine destroyer.

The Twin Cam modified and improved the valve angle hindrance with thinner, lighter valves giving more freedom for positive cam lobe design.

Nevertheless, the aggravating Evo and predecessor pushrod angles from lifter to the rocker arm remained a problem particularly with the front exhaust and secondly the rear exhaust. The center intake pushrods are much straighter. Even, the super-improved automotive style, strong Evolution hydraulic lifters continue to fall victim to bleed-down and subsequent valve train lash (play) because of the pushrod angularity.

With the advent of the Twin Cam, the location of the two cams allow almost straight up and down pushrods. Gone are the bleed down, resultant lifter ticking, and the inherent inefficiencies.

Offset Connecting Rods

Piston thrust stress is reduced because the Twin Cam connecting rods are cocked instead of having a straight shank from the big ends up to the wrist pin bushing small ends. This simple design change initiated fully in the Evolution engine reduces piston wear and frictional loss of horsepower.

Connecting Rod Ratio

There is a geometric relationship between the connecting rod length and the crankpin engine stroke. Many mechanics and riders ignore it because they do not understand the correlation. However, the ratio between the two plays a key role in the engine's breathing capability. Breathing capability of the engine is all about power and power potential. There is no power without air!

The connecting rod ratio determines by dividing the con rod length by the engine stroke.

The Twin Cam TC88 con rod ratio is 7.4375 (rod length) ÷ 4.000 (stroke) = 1.87:1. The

TC96, TC103, and CVO 110 con rod ratio is 7.4375 (rod) ÷ 4.375 (stroke) = 1.77:1.

The ratio of rod length to stroke length in internal combustion engines is generally between 2.2:1 on the high end and 1.4:1 on the low end. Longer connecting rods in relation to the stroke generate high connecting rod ratios of 1.75:1 to 2.20:1. Therefore Twin Cam con rod ratios broach the low end of the longer ratio spectrum.

Connecting Rod Length Affects the Engine's Power Band

Connecting rod length has a huge effect on the power band.

The longer the con rod is the higher the power band will position in the rpm scale. I compare the effect of a longer connecting rod to increasing a cam's duration on the power band.

1. Shorter connecting rods have the same effect as a shorter duration cam in lowering the power band.
2. *Therefore, shorter connecting rods will have a big effect on increasing bottom end torque!* Well, the Twin Cam has relatively short connecting rods. It is no coincidence that The Twin Cam is the fastest Big Twin off the line to date. This is a direct result of head design, flywheel (pork chop) weight distribution, compression ratio, and the connecting rod ratio.
3. The lower TC96, TC103, and CVO 110 lower rod ratio assists with the supercharged primary gear ratio in conjunction with the perfectly mated 6-speed transmission.

Automotive Lifters

The introduction of automotive hydraulic lifters in 1984 is a good example of increasing mechanical longevity, efficiency, and quality. Harley-Davidson engineers wisely grafted them into their motorcycles going forward with the Twin Cam. They have had great success, especially when compared with the fragile Shovelhead and Panhead hydraulics. The Twin Cam lifters rollers are further refined to produce longer life.

The lifter tappet's rollers that follow the camshaft cam lobes have more internal cylindrical roller bearings with the introduction of the Twin Cam in 1984. The external roller itself is larger.

One-Piece Flywheels

Two internal engine changes goes unnoticed by many but has enormous implications for reliability, longer service life and the reduction of vibration…the one-piece flywheel half introduced during the Evolution years.

This change improves mechanical efficiencies. It also reduces manufacturing and assembly costs. No longer does the Factory have to make these components separately. Each flywheel and mating shaft is now cast as one. This simple money-saving change has huge implications for:

Vibration reduction, which lessens substantially because pinion shaft to pinion flywheel and sprocket shaft to sprocket flywheel no longer needs truing. The flywheel and shaft are machined at a perfect and consistent 90^0. Trueness of shaft to flywheel is always perfect with the reliability that automatic CNC milling machines ensure.

1. Rigidity improves because of a reduction in potential flexing. Rigidity gives immense benefits in power transfer, efficiency, and parts longevity as well as rider comfort.

Of course, rigidity also improves with a much thicker Twin Cam pinion shaft and a beefier crank pin.

Engine Management System

Sophisticated electronic ignitions beginning with the V-Fire III fed by critical multi-sensor information began to modify ignition timing in a more exact and sympathetic manner than weak-spring loaded points ignition systems with mechanical advance-retard timing capabilities. The control of the great engine destroyer, detonation became the new mandate with government dictated leaner gas delivery. The percentage of air relative to gas kept increasing in the quest to control harmful emissions. The purpose is to incinerate more of the pollutants in the combustion chamber. This requires more heat supplied by more air. More air also increases the risk of detonation, which is uncontrolled or spontaneous ignition. The increase in heat's negative aspect is restricted by more sophisticated ignitions. Engine management must include fuel delivery correlated with ignition advance-retard curves.

Fuel Delivery

Twin Cam Carburetion

The best carburetor ever used on a Harley-Davidson, the constant velocity CV Kehein carburetor was introduced in mid year 1989. It was used until the end of 2006 when it discontinued on all Harley-Davidson models in favor of Delphi electronic fuel injection. The CV Kehein is a vacuum controlled carburetor that uses both a slide and a throttle butterfly plate to control air flow through the venturi.

Electronic Fuel Injection

However, even the best of the best CV Kehein began to wilt in light of emissions dictates. This necessitated the development of EFI or electronic fuel injection. The first EFI called Magneti-Marelli appeared on the 1995 FLHTCUI Ultra Glide Classic. H-D initially wrestled with adaptation to EFI and did not perfect this type of fuel delivery until the introduction of Delphi EFI on early Twin Cams. It is now a staple on all Harley-Davidsons. It is excellent for whatever the rider desires from performance to fuel conservation combining with reliability.

TC96, TC103, and CVO 110 Helical Transmission Gears

Harley-Davidson began using helical gears as opposed to the traditional straight cut gears in 2006 with the Dyna Glide Cruise Drive 6-speed transmission. This transmission despite some initial doubts has proved to be durable and functional.

Helical gears are quieter and stronger. The new internal transmission gear ratios match perfectly with the supercharged primary chaincase gear ratio to provide a Harley-Davidson that quite easily defies North American speed limits in combination with a daydreaming rider.

Electrics: Alternators and Starter Motors

Where do I begin? Every aspect of the electrics improves with the continuing development of the Twin Cam. Sure, some were instituted in the later Evolution years but this was a testing ground for the big splash.

Handlebar Switches

Take handlebar switches; the fragile handlebar switches in use from 1972 to 1981 burned out on a regular basis especially the starter button and the front brake light switch. Their delicacy was no match for the crude beast. In 1982, beefy and reliable switches that lasted for years replaced their weak predecessors. In 1995, these big switches became sleek and ergonomic. Lifespan increased once again instilling rider confidence.

The Wiring Harness

Wire connectors graduated from soldered terminals with tubing protection to complex plug-in heat-resistant plastic multi-terminals that easily last the lifetime of the motorcycle. When I started riding, wiring, switches, and terminals were a big deal because something was going wrong somewhere on a weekly basis.

Fuses slowly increased in number, protecting every facet of the Twin Cam wiring harness. Wiring is protected and routed away from potential harm. Vibration reduction also assists mightily. Twin Cam riders began to forget wiring and electrics because with each passing year there were fewer and fewer problems.

Charging System

Alternators (magnetic rotors and matching stators) increasingly improved. They began to generate more juice for ever-growing demands from an increasingly sophisticated motorcycle and rider.

Rectifier/regulators progressed with increasing durability along with the ability to better protect and regulate the charging system current to the battery. Speaking of batteries, their technology also improves and is now maintenance free. Vibration reduction now allows longer battery lifespans.

Starting System

Then another problematic area saw a wonderful upgrading. The superlative ever-improving Nippodenso starter motor with an incorporated solenoid-switch replaced the predecessor Prestolite and Hitachi starter motors in 1989.

Brakes: Calipers, Rotors, and Master Cylinders

The braking systems that preceded Evolution development were almost without exception an embarrassment in terms of functionality and reliability relative to motorcycle weight. Only the hardcore traditionalist diehards would tolerate them.

In 1984, with the advent of the Evolution, braking improved immeasurably both in performance and reliability. These parts lasted in service many times longer than their predecessors.

However, the Twin Cam braking systems upped the ante and outside of some initial teething problems are extraordinary in light of what had gone before. Harley-Davidson has finally discovered calipers with more than one caliper piston with superior brake rotors to match.

Need I go on? The Twin Cam is Superior!

The purpose of this chapter is to demonstrate the clear superiority of the Twin Cam over what went before in terms of reliability, longevity, and functionality. I have touched on a few of the salient points but there are many others large and small that also contribute to this modern success story.

CHAPTER XVIII

Riding the Post WWII Baby Boom Crash

To examine the phenomenal Harley-Davidson success story with its inherent weaknesses that leads to the trauma suffered in the Great Recession of 2007 to 2010, I go back to the last saviors, which were the Gang of 13 and the Evolution motorcycle. Analysts will be foolish indeed to blame the decline of Harley-Davidson on an economic cycle as severe as it was.

The 1982 Deep Recession to the 2007 Great Recession

The Evolution engine and motorcycle may never have been. Harley-Davidson was in a slow decline. The venerable Motor Company had been struggling for decades lurching from year to year. In fact, H-D had asked for tariff protection from foreign competitors as early as 1951.

However, in the nineteen-seventies, there was a glimmer of hope as a secret project motorcycle was developing in conjunction with Porsche. It was technologically far ahead of most competitors and at least equal to the Japanese…and no, it was not the V-Rod. The secretive Harley-Davidson is only now releasing information about this revolutionary Nova engine and motorcycle in the last few years.

The birth of the modern Harley-Davidson began in the deep recession of 1982 just after the spunky Gang of 13 bought this faltering company back from AMF. The post World War II baby boom had begun in earnest; the largest population bulge ever to grace North America and much of Europe. Those marketers that follow the physical and mental wants and needs of this population wave become very prosperous indeed. However, meeting the desires of one age bracket in shaping corporate affluence could become a double-edged sword if clinging too long as desires change with age. Mere 25-years later the Great Recession once again threatened to lay waste to much the darling of American capitalism accomplished. Neither recession was the cause of impending failure but the facilitator. I think that:

1. The Deep Recession of 1982 exploited Harley-Davidson's lack of quality control and absence of forward vision.
2. The Great Recession of 2007 to 2010 exposed Harley-Davidson's lack of attracting the next generations of Harley riders and once again, deficiency of forward vision that includes loaning money to buyers with no prospect of repayment.

The Fault Game

Many blame American Machine and Foundry Company known in the Harley world as AMF for Harley-Davidson's woes in the 1970's and beyond. Is this a fair assessment? Conversely, some AMF executives saw stale family ownership and mismanagement as responsible for the malaise that led Harley-Davidson to the brink of extinction. Does this judgment have any merit whatsoever? I believe so. Of course, there should be blame as well as kudos for both sides.

This era saw the development of the hugely successful Evolution that saved the day and propelled Harley-Davidson into a stratosphere of success. I will spend some time on the 15-years of history leading up to 1983, when some Evolution models saw first production. Without this history, there would be no future, no Evolution, and no modern unparalleled success story. In fact, delving into this history is fascinating as the mythology and general beliefs surrounding AMF is largely inaccurate.

As an example, the executive put in charge of Harley-Davidson by AMF was a motorcycle enthusiast, had much affection for Harley-Davidson, and was committed to the survival of this historical company. Harley-Davidson became very profitable under the tutelage of AMF, substantially increasing production. These facts run counter to prevailing folklore that an uncaring mega-corporation with little motorcycle knowledge, American Machine and Foundry had brought Harley-Davidson to the precipice of ruination. After all, the infamous AMF made bowling balls, or so the story was propagated by derisive Harley traditionalists. However, in reality, Harley-Davidson continues to honor the first man at the helm of AMF/Harley-Davidson whose name graces the Ronald C. Gott H-D Museum.

On the other hand, one truth that fully supports the problematic mythology is the quality control issues of the era. Both Harley-Davidson and AMF deserve blame for this.

The Nicest People Ride a Honda

In 1959, Harley-Davidson's nemesis Honda comes to America to meet "the nicest people." Their enduring and effective slogan, "You meet the nicest people on a Honda," provides the competition that almost destroys the already declining Harley-Davidson.

This very effective mainstream catchphrase said it all to the Harley riders of the day. We were not that bad but this nice stuff was pure baby Pablum to us. We were tough, hardy individualists. Even if we were nice, we all had some of the old west outlaw free spirit in our soul. The problem with individualism, if there is one, is that some separation is required from the mainstream.

Honda also provides the rivalry to drive Harley-Davidson to the pinnacle of excellence as both companies eventually thrive in the North American motorcycle marketplace. Actually, Honda did not miss a beat in its continual success whereas H-D had to get up to speed before accelerating onto triumph.

My earliest memories of Honda was around 1969 when someone on a 450cc Honda CB450 whose name if memory serves me correct was the Hellcat (Canada) or the Black Bomber (USA) beat all our Triumphs, Norton's, Harley's and Indians with no trouble whatsoever. This was sacrilege. We immediately socially ostracized anyone on a Japanese motorcycle not that these riders wanted to hang around with us either.

However, Harley-Davidson did not need Honda to put the nails in its coffin, as their sales 10-years earlier in 1959 were only about 17-million dollars with approximately 12,300 units. Compare this to sales of \$5,726,848,000.^{00} with a staggering 349,200 motorcycle production in 2007. [2] By 1968, Harley-Davidson was in the midst of a financial crisis. This venerable company was in dire need of help from outside resources.

The requirement for financial help was immediate with structural reorganization an ongoing solution for the future. Although Honda became a constant threat beginning in the early nineteen-seventies, it cannot accept blame for the 1968 financial crisis that had been building for many years. The reader only need reference the May 15, 1951 Harley-Davidson petition to the U.S. Tariff Commission for a 40% import tax on all imported foreign motorcycles. This onerous tariff was not against Honda or the other Japanese companies, as they had not yet begun their assault. America was once again fighting off an English invasion. This time it was Triumph, British Small Arms (BSA) and the likes of the Snortin' Norton.

The Failure of Diversification

I think Harley-Davidson family management did not meet marketplace challenges for many decades. On January 7, 1969, the AMF shareholders approved a majority buyout of Harley-Davidson stock for a measly 21-million dollars.

The AMF/Harley-Davidson Takeover

Present day, the mantra is that diversification is the key to enduring and long-term financial success. In 1970, the introduction of the ill-fated Harley-Davidson snowmobile began in limited production. It was not an AMF idea as the design preceded the buyout. Harley-Davidson has continually failed in strategic well-meaning attempts to diversify, primarily in other leisure areas such as golf carts, the Topper scooter, recreational vehicles notably Holiday Rambler, and entry level motorcycles like Aermacchi on/off road two-stroke motorcycles.

However, Harley-Davidson always returns to concentrate on their traditional strengths by selling off or discontinuing diversification attempts. I feel that Harley-Davidson could have and should have been successful at some of these expansion efforts. These failings had much to do with inadequate financing, lack of modern manufacturing methodology, and virtually no research and development funding. How can any product blossom in such a void? The idea for diversification was good except there was no infrastructure to implement and support these well-meaning ventures properly.

The big problem today for Harley-Davidson is the aging demographics of its ridership without young entry level riders to fill the void.

The Great Recession

The recession hits the Motor Company and its consumer finance arm in 2009 with devastating effect. On Thursday October 15, 2009, The Associated Press reports that Harley-Davidson announces that its third quarter profit slides by 84% because of:

Fewer motorcycle shipments to dealers.

1. Difficulties in getting loans for customers to purchase their product because of the recession.

Furthermore H-D announces that it will stop manufacturing Buell and that it is putting up MV Agusta for sale, a mere fifteen months after the purchase! H-D sells it back to the original owners in the summer of 2010.

One has to wonder about this strategy as H-D now nhas nothing that will appeal to the broader masses of riders particularly young ones.

AMF Truths and Mythologies

I realize many traditionalists will not want to hear what I have to say about the fact that AMF brought adequate financing, modern manufacturing methodologies, and R&D to Harley-Davidson. I too, hated AMF back in 1970 and decried this monstrous company for my perceptions of what it was doing to my beloved Harley-Davidson. I too, did not understand. Loyalty blinded me to reality. I disliked AMF for the same nonsensical reasons that I abhorred Honda.

I now realize that AMF was no monster and neither is Honda. The Japanese provided the competition and set the bar that Harley-Davidson needed to aspire to for survival amongst the fittest. Furthermore, a more mature attitude is that all riders are cast from the same dye of two wheels.

AMF laid to groundwork for continued existence and the unbelievable success that Harley-Davidson began to enjoy. However, a change in AMF focus to their industrial side from recreation after the departure of Rodney C. Gott and with new leadership from Tom York changed everything. Gott was a Harley enthusiast; Tom York was not. The recreational side of AMF, especially Harley-Davidson was an ongoing profit center that helped finance the industrial side of AMF. Gott kept a balance between the two. I think Tom York's reputed use of H-D capital to finance industrial expansion left insufficient funds for development of future survival projects for Harley-Davidson. This policy move provides the impetus for the Gang of 13 to rise to the challenge and get this increasingly impersonal behemoth off its back.

Failure of AMF Management

Looking at production statistics, the years of 1962 to 1965 demonstrate lackluster figures that begin with approximately 7900 units and reduce to about 3700 units by 1965 more than a 50% drop. However, production increases in the lead up to the merger with 15,600 units in AMF's first year at the helm in 1969. AMF readies for necessary massive production increases to ensure Harley-Davidson survival and importantly profitability.

- Huge increases in production begin in 1971 to 22,700 motorcycles, a 60% increase over 1970.
- In 1972, production goes to approximately 34,750; an incredible 50% year-over-year increase.
- The last year of AMF sees production increase to 48,200; an almost 40% increase over 1972.

These increases saved Harley-Davidson's bacon but at destructive quality-control cost that once again threatened survivability.

The Quality Control Crisis

The failure of AMF was to increase production ahead of a quality curve. Production needed to increase for success. Increases in motorcycle manufacturing gave substantial increases in profit. The profit increases came at huge cost. Quality control could not keep up. Quantity was king.

Then AMF focus began to utilize profits to finance industrial expansion. In short, profits did not increase quality control but went elsewhere. In my opinion, this was the failure of AMF. The riding public, including myself suffered much in these years from a substandard product. Of course, it changed my life in academia as it forced me to develop mechanical skills just to get from point A to point B.

Donny's Blasts from the Past: the Quality Control Fiasco

Imagine being a Harley-Davidson service manager back in the AMF days. This was a very stressful job as H-D riders of the day had shall I say, aggressive tendencies. My friend Teddy's considerable bulk of 450lbs served him well with the Harley crowd.

He kept four stacks of warranty files on the go on his desk at any given time. The Honda, Suzuki, and Yamaha piles were miniscule. The Harley-Davidson Shovelhead pile was always six inches thick and some days so high in danger of falling over.

Teddy and the mechanics had to cope with the onslaught of unhappy Harley customers with dark humor. The dealership employees set up a gambling pool. The betting revolved around how far the newly delivered Shovelhead Big Twins and Ironhead Sportsters would travel before the writing of the first warranty claim. Many did not make it out of the parking lot before Ted in resignation wrote the first claim of many for that bike.

The dealership owner could not take it anymore and he dropped Harley-Davidson from his lineup to reduce stress levels in his business. Interestingly, he took on H-D once again after the Evolution proved its reliability and popularity with the riding public. A major reason for the Evolution's resounding success was the *relative reliability* compared to what went before. The Twin Cam continues this trend after 1999.

Salvation: AMF Deserves Credit

AMF was to have a profound influence on the future of Harley-Davidson although most still view this merger in a negative light. Myself, I view AMF as the salvation of a struggling company that had no future if left to float on its own. Harley-Davidson based itself on post Industrial Revolution manufacturing techniques and practices that all successful American companies discarded for the efficiencies of modern methodologies. Harley-Davidson did not adapt to improving efficiencies. However, AMF certainly began the process.

Historically, it will come as a surprise to many H-D traditionalists that it was AMF that first began introducing modern quality control measures with a Quality Circle Program still in use today. This program encourages employees to express ideas to solve problems, increase the quality and effectiveness of their own work. Employees check their own work and find problems on the assembly line as they occur so that fewer warranty situations reach the consumer. This was a wonderful change that prevented the discovery of many problems afterwards in the parking lot of some dealership.

Three main programs garnered from the efficient and productive Japanese became the norm in American manufacturing:

1. The first is EI (employee involvement) that isolates problems and institutes solutions and future quality control.
2. Secondly, JIT (just in time inventory), reduces the expense of excess inventory and increases organizational control.
3. Lastly, SOC, (statistical operator control), resolves quality control issues deriving from employee inspections on the assembly line. I saw this in action while learning about the Twin Cam in 1998 in Milwaukee from Factory engineers. Employee concerns and computerization further identifies problematic areas and components. Frequent rigorous checks occur until problems resolve. Reliable components receive the less attention they deserve.

Easyriders

The Magazine

Easyriders publishes its initial magazine in 1968. It was an instant success capitalizing on the first chopper craze. At one point, Easyriders reputedly becomes the 18th-most read magazine in the world. The Easyriders formula catapults it to this status by mixing cool choppers, fictional biker tales, cartoons, tech advice, and scantily clad hippie and biker chicks. It was a pinnacle of success for me to be featured numerous times in this iconic chronicler of the lifestyle.

The Movie

Along came the 1969 movie Easyriders movie, a separate entity and not connected to the magazine but perhaps borrowing its name. The opening scene shows Billy (Dennis Hopper) and Wyatt (Peter Fonda's Captain America) doing a drug deal to finance their cross-country ride in search of America. Steppenwolf's resounding *Goddam the Pusher Man* ("the pusher don't care whether you live or die") overwhelms the striking visuals of evil Capitalism. It is a wonderful movie that explores a time in America on so many levels. I am happy that I lived through this era riding my radical chopper.

I have meant to put-to-paper an Easyriders sequel for years now. I mentally wrote this book over a few years while riding coast-to-coast.

Born to be Wild

The counterculture band, Steppenwolf was also responsible for the all time great biker hit *Born to be Wild*, ("looking for adventure and whatever comes my way").

Donny's Blasts from the Past: Steppenwolf

When I was around 15-years old, we went to dances in a local church basement in Toronto to hear many bands of the day including John Kay and The Sparrow. This band went on to play in the transitional Beatnik coffee houses to hippie hangouts, communes and flophouses on a street called Yorkville in downtown Toronto. Think Haight-Ashbury and you have the picture.

Today, forty years later, Yorkville is upscale and one of the wealthiest and commercially most expensive streets in the city. Sure, currently rich urban bikers, with their very safe walks on the wild side, ride their sanitary Harley's along Yorkville amongst the Ferraris and Lamborghini's. They replace the greasy longhaired motorcycle club members on their chopped Hawgs of the hippie era.

I gravitated from a street gang milieu into the hippie lifestyle and its peace, love and groovy philosophy bringing my motorcycle along for the ride. One day, a gang of greasers surrounded me to administer the brutal mandatory haircut of the day. I was able to fend them off for a short while as I made attempt after attempt to turn the other cheek. Peace and love were failing miserably at resolving my problem. That day I became a biker as I fought them off. I kept my hair with the realization that peace is only possible with a big fist.

Then we heard John Kay and The Sparrow split from Yorkville in a beat up old station wagon for California. No one thought the car would make it. The rest is history as The Sparrow emerged as Steppenwolf a short time later.

The Counterculture

Harley-Davidson has made many attempts to garner consumer loyalty usually via club and group associations with their product. However, the counterculture and various American subcultures embrace the iron steed as their own. The combination of Harley-Davidson marketing intertwining as an icon of the rebellious sixties and seventies laid the foundation decades later for an aging population attempting to regain their youth.

H.O.G.

Over the years, the mild successes of different attempts by Harley-Davidson, to garner customer loyalty follows by the unprecedented and unbelievable success of the Harley Owners Group.

H-D Mileage Club

In 1951, Harley-Davidson begins their H-D Mileage Club for the public. The program has evolved with twists and turns but still exists today.

H-D Owners Association

The HDOA, the acronym for the H-D Owners Association forms in 1977.

The HDOA evolves into H.O.G. and enjoys its introductory first year in 1983. H.O.G. is an instant success and becomes the largest manufacturer-sponsored bike club in the world. In fact, it becomes the biggest bike club of any kind in the world.

One Percent (1%) outlaw bikers react in disgust at the theft of their lifestyle by Harley-Davidson. As far as the original clubbers are concerned, Harley-Davidson has turned their back on the core group that supported the Motor Company through thick and thin. They feel that H-D steals their colors, insignia, and way of life. Worse, they think the Factory pasteurizes the lifestyle to allow a safe walk on the wild side for the H.O.G. Harley enthusiasts.

However, Harley-Davidson must move forward with the mainstream population to expand and survive. Small core groups of loyalists cannot adequately support H-D survival. Furthermore, the image problem of outlaw clubs is troubling. Yet, the outlaw clubs of the day personified freedom, old-west ruggedness, and individualism.

H.O.G. seeks this image to market and quite effectively so. Despite the differing points-of-view, H.O.G. is the most brilliant marketing tactic by Harley-Davidson in a sea of dazzling strategies.

The Enthusiast

The first significant marketing strategy for brand loyalty and a consumer family approach in making Harley-Davidson ownership an experience much more than just owning a motorcycle occurred in 1916. The introduction of *The Enthusiast* is popular maintaining much success to this day. Monthly publication begins in 1919. There are 50,000 subscribers by 1921. Every dealer and registered H-D owner receives *The Enthusiast* for the price of 5 cents. Today it is free.

The Black Hills Rally in Sturgis

Harley-Davidson had no part in the formation of this the largest motorcycle event in the world. This annual rally has huge benefit to the Motor Company as a celebration of everything Harley and America.

Harley-Davidson releases the FXB Sturgis model in 1980 to honor the event. It features an 80c.i Shovelhead engine, black-on-black coloring with red striping and employs both primary and a rear belt drives. The rear belt drive is bullet proof and continues to this day while the primary belt drive is fraught with problems and soon dropped in favor of a reliable primary duplex chain. The Sturgis became a very popular Harley and reincarnates both as an Evolution FXDB-Sturgis and also as a Twin Cam model.

Daytona, Laconia and Sturgis as well as a plethora of smaller rallies that mostly base on racing events has much to do in ensuring motorcycling as a way of life in America.

Willie G.

I am going to express a heretical opinion on the iconic and legendary man who is instantly recognizable by his first name and middle initial, William G. Davidson. Willie G. is the most public face of Harley-Davidson. He is beloved by his legion of fans. In the public relations arena, Willie G. is friendly and tireless, deserving the respect he earns daily.

However, I view many of his styling attempts much in the way that Ford fans relegate to the Edsel. The 1200cc 1971 Super Glide FX 1200 was far off the mark as to what H-D riders wanted or expected from the Factory. It was Willie G.'s first attempt to bring H-D in line with the chopper boom of the time. There was no budget so Willie, in his defense used parts from the Sportster like the front forks to modify the Big Twin. His custom designed the fiberglass "boat-tail" rear fender reputedly from European styling was rejected by the customizers of the day.

H-D marketed the initial FX as the *All-American Freedom Machine*. Patriotism could not rescue this design. No matter how far off the mark the first FX was, successive ones gained much deserved popularity even though H-D made another styling no-no by adapting a Sprint gasoline tank instead of the popular 3-gallon Fatbobs. I must say that H-D riders of the day had no idea this gas tank was from a Sprint. I never knew until researching this book. As it was, customizers and riders including me were replacing this tank with Fatbobs or Sportster gas tanks. I think inconsequential mass-rebellion was just around the corner if this quiet secret had become known. Inconsequential is because we forgave H-D for any and all transgressions. In any case, Willie G.'s initial design rightfully became a huge success in following years as the design modified. The very popular Low Rider and Sturgis models were direct descendents as is the rubber mount FXR and current Dyna models. Let us not forget the immensely popular 1980 Shovelhead FXWG that reincarnates many times with its latest Dyna version in 2010. The sturdy wide glide, the WG in FXWG, returns and replaces the skinny and relatively flimsy narrow-glide much to the Harley riders' joy. In fact, Willie G. is responsible for a whole line of Harley-Davidson's that bridge the Sportster with the Big Twin highway models.

I think the second mistake was the 1977 Sportster XLCR Café Racer. This black-on-black XL also had a fiberglass appendage as a rear fender. Again, Euro styling of the day had no place on an American Harley-Davidson. The bike did not look right; to me, anyway. I do not see any successive Sportsters that benefitted from the XLCR in the same way the initial FX spawned many wonderful bikes.

However, it would be difficult indeed to imagine what modern Harley-Davidson's would look like without the Willie G. influences. Perhaps H-D would not exist at all.

Saving the Hog's Bacon

I talk all the time about the future of Harley-Davidson and the inevitable changes that must occur for this outstanding company to survive into the future. Certainly, traditional styling and mechanical concepts basing on the Sportster and Big Twin must fall by the wayside in the next decade.

The Little Known AMF Story

The little known American Machine and Foundry story is that of the very secretive Nova Project. AMF experimented extensively with this new ultra-progressive design motorcycle. The truth is that while AMF did not quite save Harley-Davidson from extinction, it made many of the prerequisite moves and laid the groundwork for the Gang of 13 to build on.

Dare I say that AMF engineered the first 5-speed transmission, rubbermount frames, and rear belt drives? Furthermore, AMF instituted the beginning of the Evolution engine in 1977 over three years before the buyout by H-D management. This reviled company also had a hand in the revolutionary head design, unleaded gas valves and seats, offset connecting rods, improved piston and ring design as well as many other developments incorporated into Evolution design.

Harley-Davidson traditionally bases on the awkward and inefficient 45°-cylinder angularity but attempts developing quite effective transition motorcycles via the 60° V-Rod and the recession-casualty 72° Buell 1125R. Most view this as first time utilization of newer technology by the Motor Company. However, over three decades ago in 1976, AMF/Harley-Davidson began development of new two, four, and 6-cylinder water-cooled motorcycles whose technology was certainly equal to if not ahead of the Japanese at that time. The projected launch date for the Nova was during 1981.

The 1976 Pinehurst Meetings set the Future

Pinehurst was a resort in North Carolina where a two-pronged strategy for the future evolved for the Harley-Davidson division of American Machine and Foundry in mid-1976.

The strategy was superb. It only failed due to a lack of resources to finance both prongs of the plan. However, either approach had huge potential to work on its own. The implementation of both strategies could possibly have made Harley-Davidson the dominant player in motorcycling worldwide. The dual strategy was to:

1. First refine the Shovelhead into an evolution of design improvement to make a next generation engine reliable and fast. Hence, the name Evolution became very appropriate.
2. The second strategy was the Nova Project. The Nova was a new motorcycle to conquer the smaller bike market and give a high tech alternative to traditional Harley-Davidson's.

The Ultra Secret Harley-Davidson/Porsche Nova

The best choice was to evolve both concepts in tandem but this was not to be.

The Nova models were double overhead cam (OHC), 60° V-Twin water-cooled motorcycles in various two to six cylinder configurations ranging from 400cc to 1500cc. The shorter stroke Nova without pushrods could safely rev to the 10,000 rpm levels. Compare this to the Twin Cam redline of 5500 rpm.

AMF decided that in-factory engineers would handle the Evolution engineering while Porsche was subcontracted to develop the Nova. Porsche, as the reader may know also mightily assisted in the development of the V-Rod decades later.

About 30-Nova engines with 2000 hours testing and a dozen complete, running motorcycles logging 100,000-test miles result without major problems occurring. One of the prototypes even met the strict California emission standards of the day. The Evolution went through 250,000 miles of road testing so the Nova was well on its way.

The main thrust for Nova development was in the smaller categories that were dominated by foreign suppliers in America as well as abroad. These smaller Novas, particularly the 2-cylinder 400cc and 500cc as well as the 4-cylinder 800cc models could meet the Japanese head on for small bike market competition. More importantly, they would allow entry-level riders into the Harley-Davidson fold. The smallest Harley at the time was the 1000cc 2-cylinder V-Twin Sportster that was much too large and expensive for young enthusiasts.

Furthermore, the Nova would meet the desire for speed in a performance-oriented marketplace. Certainly, the Nova heavyweights, consisting of a V4 1000cc and V6 1200cc and V6 1500cc models would compete with both the H-D Sportsters and Big Twins but also the vaunted Gold Wing and other big cruisers that would soon challenge Harley-Davidson dominance of that market.

The V6 1500cc 60^0-Nova model had up to 135 horsepower output. This is remarkable because it is about 2 ½ times the horsepower output of the Big Twins of the day. The powerhouse Nova certainly would have revolutionized American motorcycling.

The Nova Project launched in the 1970's almost came to fruition and missed going into production primarily because of the Gang of 13, 1981-company buyout. The new owners unwillingly abandoned the Nova Project, as there just was not enough money to put both the Nova and the Evolution into production. AMF resources would have ensured a good shot at success.

The Gang of 13 was visionary of success that no one else but AMF could see. In retrospect, given the hard choices, I feel the new owners prioritized in the right order. However, the crisis that H-D began to face in the latter months 2007 was due to:

1. The passing baby boom demographics.
2. The recession. Don't ever believe the recession was a greater factor because the aging population matured through their attempt to regain their youth. Crashing sales were in the cards for a long time.
3. Importantly, H-D never successfully developed an entry level bike to compete with the Japanese that was affordable to young people. Yes, perhaps the Nova in its many variations could have saved the Hog's bacon over three decades later by both garnering the loyalty of new generations and spreading Harley-Davidson mainstream appeal to a larger purchasing audience.

However, the financial choice for the Gang of 13 was to modernize the V-Twin Shovelhead whose warranty problems were sinking the Motor Company relative to its competitors or pursue the Nova.

The Japanese

The Japanese had more than quality. Their arsenal included acceleration and speed combining with good braking and handling. They could design, tool-up and build a new motorcycle in a mere eighteen months. The flavor of the day could easily be accomplished with this organizational skill and dexterity. On top of this they had lower prices.

The Gang of 13 took over a failing company or did they? By 1982, H-D sales went into a tailspin with plunging new model production. The USA was in a deep recession. Money was exceedingly tight as interest rates skyrocketed into the high teens and beyond. Adding to the perfect storm was the flood of Asian imports that many believe were being sold in the U.S. below their manufactured costs.

Whether this was true or not, how did a small country a half-world away manufacture a quality product that was faster, handled better, and was less expensive? Furthermore, these import motorcycles were more functional and appealed to the American public of every age group. Well, of course they did because USA motorcycle manufacturing offered old clunker styling that was slower, did not handle well, and broke down all the time! And for all of this, Harley-Davidson's cost more. Insulting if one thinks about it.

It is not that the Evolution was that good relative to their competitors because it was not. However, the Evolution and its successor, the Twin Cam was stellar relative to what went before. I was a loyal Shovelhead rider, necessarily becoming a mechanic along the way. I like the rest of my ilk would never consider riding any other product. I did not care that a Honda might be functionally better, less expensive, and not require my newfound mechanical skills.

Honda simply did not give what my psyche craved. This new Evolution Harley may still have cost more but had improved styling, acceleration, handling, braking, electrics, fuel delivery with integrated ignition management and a lot more plus it did not break down as much…and that was good enough for us.

You might meet the nicest people on a Honda but Harley riders are all about cool. They adapt a pseudo-outlaw lifestyle that emulates freedom and individualism. They spend much of their time adopting one charity or another to prove they really aren't bad. Many charities benefitted greatly during the Harley boom. Can these riders be contesting the Honda mantra of niceness? In fact H-D riders are so cool that society and especially the police forgive a whole generation of the middle-aged for roaring around on straight pipes rattling windows and setting off car alarms. And so went the Evolution and Twin Cam years.

The Gods of Capitalism Giveth and Taketh Away

AMF really gave the Gang of 13 a platform from, which to launch. These new guys were brighter than bright. They put a management team together that knew no bounds in success. I am sure that Marketing 101 in every business school teaches and will continue to teach their brilliant story. Harley-Davidson became the epitome of American manufacturing and marketing, the darling of capitalism at its finest. Think about it! How could a rusty old manufacturer whose time had drifted by reach such pinnacles of success? Well, H-D had a little help along the way with two main sociological factors:

1. The post World War II baby boom, the aging bulge in American demographics *looking for adventure and whatever (safely) came their way.*
2. A generation that worked hard; raised families and then looked back at what they had missed in their youth. Harley-Davidson embodied the freedom and adventure they lacked.

Harley-Davidson was granted two decades by the gods of capitalism to plan a lasting and viable future. It sought to be the motorcycle of mainstream America. The world would follow. Harley-Davidson almost pulled it off. It reigned in the beast taming vibration, instituting quality control and cool designs. The Motor Company updated technology both in their manufacturing venue and in the product itself. H-D balanced on a near-impossible fulcrum, maintaining tradition on one side and complying with environmental dictates on the other.

The Twin Cam introduced with great success. H-D continued to grow and prosper. I have always viewed the Twin Cam as a transitional model embracing the past but leading into a future of overhead cams and water jackets. The V-Rod's technological marvels are a wonderful attempt but as much as the Factory hoped, mainstream Harley riders did not take the bait en masse. After all they had their psychological needs.

I really like the V-Rod but I love my technologically inferior main steed. Well then, the Buell would appeal to the younger generation? Sure, but it cost more and was not quite as good as the Japanese and European street bikes. The Buell improved each year. These attempts did not prevent dark clouds from appearing on the horizon:

1. Inexorably, the post World War II baby boom's bulge has grown older, losing interest in reclaiming youth with interests shifting elsewhere. Who is to take over this downsizing market? Who will be left to support the Motor Company in the style it has become accustomed?
2. In my humble opinion, the masters of marketing did not fill the coming void of consumers. I think H-D is good at pretty much everything except lowering prices for the incoming generations. Nor have they developed affordable and desirable product lines for the youth. Certainly, the Factory began to enjoy economies of scale in manufacturing. I for one do not think they have used their profits wisely for continued prosperity.

Will I continue to ride a Harley at age 63? Sure I will but I was riding them before they became cool. I am not a dentist looking for a safe walk on the wild side or a movie star acquiring the in-bauble of the day. No offence to dentists or movie stars because I know hardcore Harley riders from both professions but I am sure the reader gets my drift.

The Evolution motorcycle followed by the Twin Cam saved the Hog's bacon but a new savior is now required.

What Goes Around Comes Around

Harley-Davidson has continually failed in strategic well-meaning attempts to diversify, primarily in other recreational areas such as golf carts and entry level motorcycles like Aermacchi on/off road two-stroke motorcycles. However, in 1978, Harley-Davidson wisely returns to concentrate on their traditional strengths by selling Aermacchi to Cagiva. Cagiva grows into the very successful and prestigious Italian motorcycle conglomerate, MV Agusta Group.

Many times Harley-Davidson ideas were ahead of the curve. For example, Aermacchi or a similar company would enjoy much success under a separate Harley-Davidson banner in later years when H-D had the resources and muscle to make it a success. More importantly, the void of younger riders joining the ranks of Harley-Davidson rider enthusiasts to replace the current aging demographics would resolve and be a major factor in future success.

Lo and behold, in 2008 the Motor Company purchases Italy's MV Agusta Group for a reputed £65,000,000.(90). MV Agusta Group owns Cagiva, which purchased Aermacchi from Harley-Davidson three decades earlier. Harley now temporarily owns some happening motorcycles of other genres. Importantly, they are European and not Japanese.

Is this a good purchase? Will it complement the void in Harley-Davidson?

Well, I know the timing is not right since the purchase occurred in the initial throes of the Great Recession in 2008.

1. Secondly, while I believe it a good purchase for probably too much money in light of the timing, I think it too little, too late.

Too late for sure as the Motor Company announces the sale of MV Agusta Group as the recession for this venerable company deepens in October 2009. However, it is more than a recession for Harley-Davidson. It is recession combining with failure to adapt to a new and younger marketplace. H-D further announces that Buell will cease production.

In the summer of 2010 the former owners, the Castiglioni family buys back MV Agusta from Harley-Davidson. H-D must now rely exclusively on an aging population to carry the brand in North America. I think India and like countries will be the salvation of the Motor Company.

Will Harley-Davidson Survive?

The rumor mill swirls mercilessly. Too large, too ostentatious dealerships are going out of business at an alarming rate. H-D stock is on a downspin. Layoffs are occurring. Downsizing is in earnest amid rumors that the venerable Harley-Davidson has become a takeover target.

I for one am optimistic. I feel vindicated that the arrogant suits amongst some fine dealers are being bought down more than a few notches. As always, I believe the good business people without debt burden will survive for the most part. Harley-Davidson will live to tell the tale as always. It may not quite look the same but I have no fear that I will ride a Harley throughout my lifetime. In fact, the Motor Company may revert back from the mainstream to niche status in the USA marketplace.

H-D marketing genius still glimmers. Watch Ultimate Fighting (UFC) to view the H-D Bar & Shield logo prominently on the Octagon mat. H-D transfers its dated dependence on the pasteurized outlaw biker lifestyle to the rugged flavor of the day…those that resolve differences physically instead of litigiously.

Harley-Davidson is not bereft on innovative ideas as it seeks success in India of all places with a huge population and a burgeoning middle class. The Great American Freedom Machine becomes available in a selection of twelve models for 2010; the Sportster XL883L, XL1200N, XL883R; the Dyna Glide FXDB and FXDC; the V-Rod VRSCDX; the Softail FLSTF Fat Boy and FLSTC Heritage Classic along with the FLHR Road King, The FLHX Street Glide, and the FLHTCUSE Screamin' Eagle Ultra Glide. Furthermore, the premiere model will be a special Fat Boy marketed with custom paint with Indian color accents. I quote the managing director of Harley-Davidson India, Anoop Prakash. "Over the past year (2009) we have listened to riders across India at our many events, and we have produced a lineup to *stir their soul*."

Therefore, more than cost cutting and downsizing is going on with the flip side of the coin showing expansion in other markets. Obviously, Harley-Davidson is not confident of its home market to pull it out of the quagmire. However, with true American spirit H-D is reaching out for salvation coincidentally and justifiably in a land blamed for much of the outsourcing of American jobs. I have one question. Is the endgame to manufacture in India as opposed to the United States if successful with the foray into this new marketplace?

Surprise, surprise; Harley-Davidson will assemble select models in India at its CKD (complete knock-down) assembly facility in Haryana beginning in mid-2011. After Manaus Brazil, India is the second country to assemble Harleys' outside the USA. There are currently three dealerships in India; Banjara Harley-Davidson in Hyderabad; Capital Harley-Davidson in Delhi, and Himalayan Harley-Davidson in Chandigarh.

Harley-Davidson's inability to meet future EPA regulations with an air-cooled, pushrod-operated engine may see rescue in India and like countries that are undergoing Industrial Revolution with necessary collateral pollution. H-D exhaust and noise emissions will pale in comparison.

Perhaps, current American tooling and production will transfer to countries like India who will preserve H-D tradition while the new USA models become water-cooled with overhead camshafts.

I can only seek solace by reaching back to remember the first times I rode an Evolution. Awestruck would be an appropriate phrase describing the feeling. My Shovelhead just never felt the same afterwards. The Evolution motorcycle was truly a phenom of its time. The Twin Cam carries on the evolutionary trend.

Evolution must continue perhaps at a revolutionary pace in order to ensure the survival of the company and product that so many of us love.

[1] Harley-Davidson Motor Company Minutes 1965.

[2] Harley-Davidson website, www.harleydavidson.com. Company: Harley-Davidson, Inc. 2007 Annual Report.

CHAPTER XIX

Deciphering the Twin Cam Serial Numbers

The 17-digit VIN (vehicle identification number) number is stamped on all Softail and Dyna models into the right side frame neck or more correctly on the right side of the frame backbone at the rear of the steering head. The FLT series VIN is stamped in an inaccessible read-location on the front of the frame yoke that houses the lower fork stem. The bulky faring and wiring loom obscures the serial number. Why H-D did this is beyond me.

On all models the VIN repeats further down the right frame down tube in an easy-to-read location on a sophisticated label called a Federal Certification Label. This label is metallic, virtually indestructible and next-to-impossible to remove. I know because I have tried during customizing efforts. I wanted to remove it, paint or powdercoat the frame and then replace it: no chance.

An abbreviated stamped-in VIN also appears on the left-hand engine case.

Modern Serial Number Origins

In 1980, the USA Federal government mandated that all manufacturers selling vehicles in America devise a consistent and sophisticated VIN serial numbering system than what was in use at the time for three main reasons:

1. Uniformity to prevent confusion.
2. Theft deterrence.
3. Enable and enhance enforcement.

In 1981, the current standardized 17-digit code evolved with a few differences from the past.

1. Never had Harley-Davidson used so many letter-numerals in a serial number.
2. The previous 1970 to 1980 engine numbers and frame numbers were identical.
3. The new 17-digit coding instituted in 1981 officially transferred the VIN location from the engine to the frame. This really began in 1970 but not with this sophistication level.
4. The 17-digit VIN system was instituted worldwide for automobiles, trucks, motorcycles, and off-road vehicles.
5. The engine number directly relates to the frame VIN number but is attenuated, which means it has less characters (10) although the longer VIN contains the engine number-letters.

6. The new system includes numerals and letters that indicate a standardized country of origin; the particular manufacturer of the vehicle; the standard weight grouping delineation; the vehicle model; engine identification; a verification number; the model year; the assembly plant where produced; and a six digit production number at the end.

The Information Order of the 17-digit VIN

Interpreting Twin Cam Vehicle Identification Numbers

1. The 17-digit system rearranges the order of information in the VIN.
2. The posident star stamp encasing the frame VIN number used from 1970 to 1980 ceases in 1981. This was simply a complex star shape stamping that places before and after both the serial frame VIN and the engine serial number.

However the shortened engine number, which began use in 1981 still retains posident star stamping before and aft the engine serial number to present day.

The new system includes coding to give:

1. Country of origin, where the 1st digit delineates this. For example the United States vehicles begin with a 1 while vehicles for foreign sales like Canada and Europe begin with the numeral 5.
2. Manufacturer: the next two letters (2nd and 3rd digits) after country of origin are HD for Harley-Davidson.
3. The 4th digit denotes the weight group; motorcycles are classified according to weight with Harley-Davidson being in the heavyweight classification.

Vehicle Identification Number (VIN) Weight Class Designations:

1981 to Present 3rd Designate in VIN (4th letter/numeral)

Number	Weight Classification	Engine Size
1	Heavyweight	901cc +
2	Middleweight	351cc-900cc
4	Lightweight	350cc -
8	Sidecar	

1. The 5th and 6th digits are letters that denote the particular model. See the chart below named *VIN Codes for Twin Cam H-D Models* for letter-model designations.
2. The 7th digit is a letter or numeral that denotes the engine identification.

The 7th Letter/Numeral in the 1981-Present VIN Denotes Engine Type

Engine	Year	Size	Induction	Designation
Twin Cam	1999-2006	TC88 A	Carburetor	V
Twin Cam	1999-2006	TC88 B	Carburetor	Y
Twin Cam	1999-2006	TC88 A	EFI	W
Twin Cam	1999-2006	TC88 B	EFI	B
Twin Cam	2007-Present	TC96 A	EFI [1]	4
Twin Cam	2007-Present	TC96 B	EFI [1]	5
Twin Cam	2007-Present	CVO110 A	EFI [1]	8
Twin Cam	2007-Present	CVO110 B	EFI [1]	9
Some other examples and designations				
Shovelhead	1981-1986	1340cc	Carbureted	K
Evolution	1984-1999	1340cc	Carburetor	L
Evolution	1995-1999	1340cc	EFI	R
Ironhead XL	1981-1985	1000cc	Carbureted	H [2]
Evolution XL	1986-Present	883cc	Carbureted	M
Evolution XL	1986-1987	1100cc	Carbureted	N
Evolution XL	1988-Present	1200cc	Carbureted	P
Evolution XL	2007-Present	883cc	EFI	2
Evolution XL	2007-Present	1200cc	EFI	3
Evolution XL	Precision cooled	1200cc	EFI	6
Revolution (V-Rod)	2002-Present	1130cc	EFI	Z
Revolution (V-Rod)	2007-Present	1250cc	EFI	H [2]
V-Rod Screamin' Eagle	2005-Present	1300cc	EFI	G [3]

[1] All TC96 and CVO 110 engines use EFI. The last year for carburetion on a Harley-Davidson engine was 2006, no matter the model or type. The TC96 and the CVO 110 began in 2007.

[2] The 1250cc EFI V-Rod's use an H for engine type as does the now defunct 1981 to 1985 Ironhead Sportster, which is carbureted.

[3] The 7th digit in a 1250cc V-ROD VIN can be either H or G. The H is for a VRSCDX - Night Rod Special in 2008 or 2009 VRSCAW. A 2005 VRSCSE has a G in the 7th position. The 1250cc standard V-Rod's used an H and Screamin' Eagle V-Rod's used a G.

[4] The 8th digit gives the introduction date and type.

The Introduction Date is the 8th Digit in the VIN Pre-2009

Regular Introduction Date [1]	1
Midyear (MY) introduction [2]	2
California only [3]	3
Special Edition [4]	4
California Special Edition [4]	5
MY California	6

[1] Usually begins in late July or early August of the previous year (2011 models introduce in July-August 2010).

[2] Midyear (MY) production usually begins in late spring of the model year. MY production usually has some new features, corrections or modifications for the next year production.

[3] California models are different in that they usually contain the most stringent emissions controls known as CARB (California Air Resources Board).

[4] Special editions are usually limited production runs of specialty models for particular use or groups or may simply indicate cosmetic changes.

The Introduction Date and Type is the 8th Digit/Letter in the VIN Post-2009

Regular Introduction Date: 49-State [1]	1
Midyear (MY) introduction: 49-State	2
California only	3
Special edition [2]	4
Special Edition: California [3]	5
MY introduction: California	6
Regular Introduction Date: Canada	A
MY Introduction Date: Canada	B
Regular Introduction Date: HDI	C
MY Introduction Date: HDI	D
Regular Introduction Date: Japan	E
MY Introduction Date: Japan	F
Regular Introduction Date: Australia	G
MY Introduction Date: Australia	H
Regular Introduction Date: Brazil	J
MY Introduction Date: Brazil	K

The letter I is not used as a designate because it might be confused with the numeral 1.

[1] EPA, CARB, European TÜV, HDI, Brazil, Japan, Australia and Canada may have different calibration requirements. These are indicated by the Introduction Date and Type 8th digit/letter in the VIN

[2] An introduction date of 4 indicates cosmetic changes or perhaps a unique introduction date for that particular 49-State model.

[3] An introduction date of 5 indicates cosmetic changes or perhaps a unique introduction date for that particular California model.

California and 49-State models blend to become 50-State models in 2010 with the introduction of exhaust catalysts. However, this may not stay this way as California is necessarily aggressive in curbing pollution.

The 9th digit is a verification number that varies between the numerals 0 and 9 or may be the letter X.

The model year denotation is via the 10th character in the VIN, which in the case of the Twin Cam may either be a letter or a numeral depending on year. The new 17-digit VIN uses a letter to designate the year of the bike up to and including 2000. In 1999 the letter X denotes this year for both the Evolution Softail models and all Twin Cam models. In 2000, all Twin Cam models use the letter Y. The Twin Cam begins the use of a numeral in the year 2001 instead of a letter to designate year beginning with a 1 and so on. Obviously the year 2010 creates another change for year designation since using the digit 10 will increase the 17-digit VIN to 18. So, 2010 begins using the alphabet once more, beginning with A. The letter A has no previous use for model year designation in a VIN. However, B and the rest of the alphabet do! The letter B will designate a 2011 motorcycle. It also assigned a 1981 model when the alphabet was first used to designate year. It follows that C will indicate a 2012 motorcycle as it will also a 1982 model.

Finding the Year

17-digit Frame VIN Serial Number			10-digit Engine Serial Number	
10th Digit			4th digit	
1999	X[1]		1999	X[1]
2000	Y		2000	Y
2001	1		2001	1
2002	2		2002	2
2003	3		2003	3
2004	4		2004	4
2005	5		2005	5
2006	6		2006	6
2007	7		2007	7
2008	8		2008	8
2009	9		2009	9
2010	A		2010	A
2011	B		2011	B
2012	C		2012	C
2013	D		2013	D
2014	E		2014	E
2015	F		2015	F

[1] The letters I, O, and Q are not used in the VIN's because they may confuse with the numbers 1 or 0. The letter U is also not used but for what reason I do not know. The numeral system from 2001-on does not use the zero (0) because of its confusion with the letter O.

- This year-identification letter (1981 to 2000) or numeral (2001 to 2009) or the reversion back to a letter beginning in 2010 is the 10th character in the longer VIN.
- However, year-identification is found with the 4th character in the shortened engine number.

The 11th digit, which in this case is always a letter, is the motorcycle assembly plant code. This will either be York Pennsylvania, Kansas City, Tomahawk, East Troy or perhaps in Milwaukee itself a long time ago. Twin Cam engine production currently takes place in Milwaukee but assembly occurs in York Pennsylvania.

Assembly Plant Code: 11th Digit (letter): 1981 to 2009

Plant (City)	Letter designation
Milwaukee Wisconsin	J or an M
York Pennsylvania	Y
Kansas City Missouri [1]	K
Tomahawk Wisconsin	T
Manaus Brazil [2]	M
Buell: East Troy Wisconsin [3]	3

[1] Current Sportster/Dyna assembly is in Kansas City. Touring and Softail production is in York. However, early in 2009, Harley-Davidson announces year-over-year sales decreases for the quarter of about 13%, layoffs of about 11% (1100 workers) going into 2010 and cutbacks in production up to 13% in 2009 after similar cuts in 2008. At this point, consolidation makes anything possible on a cost effective financial basis. For example, H-D will reportedly close its Franklin distribution center, combine parts and accessories and accomplish general merchandise distribution through a third party. As part of the move, Harley will merge its two Milwaukee engine and transmission production facilities to its Menomonee Falls location. It will also amalgamate some facilities like paint and frames into a single facility in York, Pennsylvania. There are losses in its finance arm, which gave the most liberal loans for almost any year Harley-Davidson in my area. I know some of the people and you wouldn't loan them a nickel if they gave you ten cents collateral so these losses are no surprise to me. There are rumors of H-D bankruptcy but I don't buy this for one minute. Nevertheless, we may see some merging of operations that affect where different models are built.

[2] There is good reason to begin operations in South America as it is a huge untapped market full of macho people. Manufacturing costs are inexpensive and Brazil is in the heart of the Southern Hemisphere, which is a long way from the USA. The first assembly plant opens outside of America in of all places, the Amazonian city of Manaus in Brazil in 1998. I don't know the rationale for this particular location except there may have been some heavy government grants sweetening the pot.

[3] Erik Buell is wisely appointed Chairman of Buell after the Motor Company purchases a remaining 49% interest in the Buell Motorcycle Company in 1998. Harley-Davidson announces the November and December suspension of Buell motorcycle production during the Great Recession in late 2009. Before the end of that year, the Motor Company further announces the formal end of production for Buell entirely causing the permanent loss of 180 jobs.

Assembly Plant Code: 11th Digit (letter): 2010 to 2039

Plant (City)	Letter designation
Tomahawk Wisconsin	A
York Pennsylvania [1]	B
Kansas City Missouri	C
Manaus Brazil	D
Buell: East Troy Wisconsin [2]	E

[1] In 2009, Pennsylvania almost loses the Harley-Davidson facility in York. Negotiations begin in earnest with other locales like Indiana and Kentucky. Government grants factor heavily in the give and take as do production costs. Pennsylvania wins out with a combination of government grants and employee wage concessions. However, the workforce reduces substantially in crushing response to the Great Recession of 2007 to 2010 as well as the passing of the post WWII baby boom demographics.

[2] The E designate becomes a moot one as Harley-Davidson announces the suspension followed by the termination of Buell motorcycle production during the Great Recession in late 2009

The 12th to 17th digits, which are numerals, are the sequential number of production but the starting number may vary.

The Engine Serial Number Coding

The new 1981 to present engine code;

1. Relates directly to the VIN but is not used for licensing purposes.
2. The engine number has 10 characters not 17.
3. The 10-characters *have* the posident star at either end.
4. The model year is the 4th character and again the same letter/numeral as used in the VIN.
5. 1981 to early-1983 engine numbers are stamped on the upper right side of the engine case. Harley-Davidson has midyear production (MY) as well as beginning year production.
6. In late-1983 (MY), the engine serial number moves back to the upper rear left side of the engine.
7. Later the engine number moves to the upper center of the left engine case.

Example; if the frame VIN number is 1HD1GDV1*3K110000, the engine number will be GDV3110000

Twin Cam Engine Serial Numbers 1999 to 2009

Example; VIN is 1HD1GDV1*3K110000; engine number GDV3110000

Digits	Engine # location	VIN location	Indicates	In this case
GD	1st/2nd digits	5th/6th digits	Model	FXDL
V	3rd digit	7th digit	Engine	TC88 carburetor
3	4th digit	10th digit	Year	2003
110000	5th to 10th digits	12th to 17th	Production number	

Frame number: 5HD1GDV1*3K110000
Engine number: GDV3110000

5 HD 1 GD V 1 * 3 K 110000
GD V 3 110000

5 = manufactured in USA for foreign sales (1 = made in USA for domestic sales)
HD = Harley-Davidson
1 = 901cc or bigger (heavyweight)
GD = model designation (FXDL in this case)
V = engine style (TC88 carbureted in this case)
1 = regular introduction date: (2 = midyear production; 3 = California production only; 4 = special edition; 5 =special edition California only)
* May be X or any digit between 0 and 9
3 = model year (2003)
K = assembly plant (Kansas City)
110000 = sequential production number

Example:
Frame number 1HD1PR81*8Y 111000
Engine number PR8 8 111000

1 HD 1 PR 8 1 * 8 Y 111000
1 = manufactured in USA for domestic sales (5 = made in USA for foreign sales)
HD = Harley-Davidson
1 = Heavyweight: 901cc or bigger
PR = model designation (FLHTCUSE[3] in this case)
8 = engine style (110c.i): 4 = 1584cc *(96c.i)
1 = regular introduction date (2 =midyear production; 3 = California regular production; 4 = cosmetic changes; 5 =cosmetic changes California only); 6 = California MY (midyear)
* May be X or any digit between 0 and 9 VIN check digit
8 = model year (2008)
Y = assembly plant (York Pennsylvania)
111000 = sequential production number

Twin Cam Engine Serial Numbers: 2010 to 2039

Example; VIN is 5HD1KB41*AB110000; engine number KB4A110000

Digits	Engine # location	VIN location	Indicates	In this case
KB	1st/2nd digits	5th/6th digits	Model	FLHX
4	3rd digit	7th digit	Engine	TC96A EFI
A	4th digit	10th digit	Year	2010
110000	5th to 10th digits	12th to 17th	Production number	

Frame number: 5HD1KB41*AB110000
Engine number: KB4A110000

5 HD 1 KB 4 1 * A B 110000
KB 4 A 110000

5 = manufactured in USA for foreign sales (1 = made in USA for domestic sales)
HD = Harley-Davidson
1 = 901cc or bigger (heavyweight)
KB = model designation (FLHX in this case)
4 = engine style (TC96A 1584cc EFI in this case)
1 = regular introduction date: 49-State calibrated models
* May be X or any digit between 0 and 9
A = model year (2010)
B = assembly plant (York Pennsylvania)
110000 = sequential production number

CVO Screamin' Eagle Models

The CVO (Custom Vehicle Operation)

The CVO program began in 1999, bringing back the very popular FXR discontinued in 1994. The 1999 and 2000 FXR CVO models were the only Evolution 1340cc rubbermount models produced after 1998. SE or S.E. is the acronym for Screamin' Eagle.

1999 FXR²: CVO S.E. Evolution 1340cc 80c.i (900 produced)
FXR³: CVO S.E. Evolution 1340cc 80c.i (900 produced)

2000 FXR⁴: CVO S.E. Evolution 1340cc 80c.i (last H-D Evolution motorcycle)
FLTRSEI: CVO S.E. Twin Cam Road Glide EFI* 1550cc (95c.i)

2001 FXDWG²: CVO S.E. Dyna Wide Glide 1450cc (88c.i)
FLTRSEI²: CVO S.E. Road Glide EFI 1550cc (95c.i)

2002 FXDWG³: CVO S.E. Dyna Wide Glide 1450cc (88c.i)
FLHRSEI: CVO S.E. Road King EFI 1550cc (95c.i)

2003 FLHRSEI^{2}: CVO S.E. Road King EFI 1690cc (103c.i)
FXSTDSE: CVO S.E. Softail Deuce 1550cc (95c.i)

2004 FXSTDSE^{2}: CVO S.E. Softail Deuce 1550cc (95c.i)
FLHTCSE: CVO S.E. Electra Glide Classic 1690cc (103c.i)

2005 VRSCSE: CVO S.E. V-Rod Custom 1250cc
FLSTFSE: CVO S.E. Fat Boy 1690cc (103c.i)
FLHTCSE^{2}: CVO S.E. Electra Glide Classic 1690cc (103c.i)

2006 VRSCSE^{2}: CVO S.E. V-Rod Custom 1250cc
FLSTFSE^{2}: CVO S.E. Fat Boy 1690cc (103c.i)
FLHTCUSE: CVO S.E. Ultra Classic Electra Glide 1690cc (103c.i)
VRSCXSE: CVO S.E. V-Rod Destroyer 1300cc. The V-Rod Destroyer is for race only with a planned production run of 250, which was primarily for dealer use only, to promote V-Rod sales through racing prowess. This is some wild bike, extraordinary by H-D standards. Demand caused the Factory to increase production to 750 units, which was too many so unsold units are still on dealer floors in 2009. Retail MSRP was $31,000.(0) U.S.

2007 FLHRSE^{3}: CVO S.E. Road King 1800cc (110c.i)
FLHTCUSE^{2}: CVO S.E. Ultra Classic Electra Glide 1800cc (110c.i)
FXDSE: CVO S.E. Dyna 1800cc (110c.i)
FXSTSSE: CVO S.E Softail Springer 1800cc (110c.i)

2008 FLHRSE^{4}: CVO S.E. Road King 1800cc (110c.i)
FLHTCUSE^{3}: CVO S.E. Ultra Classic Electra Glide 1800cc (110c.i)
FXDSE^{2}: CVO S.E. Dyna 1800cc (110c.i)
FXSTSSE^{2}: CVO S.E. Softail Springer 1800cc (110c.i)

2009 FLTRSE^{3}: CVO S.E. Road Glide 1800cc (110c.i)
FLHTCUSE^{4}: CVO S.E. Ultra Classic Electra Glide 1800cc (110c.i)
FXDFSE: CVO S.E. Dyna Fat Bob 1800cc (110c.i)
FXSTSSE^{3}: CVO S.E. Softail Springer 1800cc (110c.i)

2010 FLHTCUSE^{5}: CVO S.E. Ultra Classic Electra Glide 1800cc (110c.i)
FLHXSE: CVO S.E. Street Glide 1800cc (110c.i)
FLSTSE: CVO S.E. Softail Convertible 1800cc (110c.i)
FXDFSE^{2}: CVO S.E. Dyna Fat Bob 1800cc (110c.i)

2011 FLHTCUSE^{6}: CVO S.E. Ultra Classic Electra Glide 1800cc (110c.i)
FLHXSE^{2}: CVO S.E. Street Glide 1800cc (110c.i)
FLSTSE^{2}: CVO S.E. Softail Convertible 1800cc (110c.i)
FLTRUSE: CVO S.E. Road Glide Ultra 1800cc (110c.i).

*First use of electronic fuel injection (EFI) on production Harley-Davidson's is in 1995. The suffix I after a model description indicates the bike has EFI from 1995 to 2006. If there is no suffix indicating EFI during these years, then the bike is carbureted. All Harley-Davidson's have EFI as carburetion has been discontinued because of EPA emissions controls. The I designation for EFI is also no longer used from 2007-to-present, which can cause confusion.

VIN Codes for Twin Cam H-D Models

Softail Models			Touring		
Code	**Model**		**Code**	**Model**	
BH	FXST	Standard (carb)	DD	FLHT	Electra Glide Standard
BJ	FLSTC	Heritage Classic (carb)	DG	FLHTC**	Electra Glide Classic
BK	FXSTC	Softail Custom (Evolution)	DJ	FLHTC	Electra Glide Classic
BL	FXSTS	Softail Springer	FB	FLHR (I)	Road King EFI
BM	FLSTF	Fatboy (carb)	FC†	FLHTCU (I)	Ultra Classic EFI
BN	FLSTN	Deluxe (Nostalgia)	FD†	FLHR	Road King carbureted
BR***	FLSTS	Heritage Springer (carb)	FF†	FLHTC (I)	Electra Glide Classic EFI
BR***	FLSTSC	Heritage Springer Classic carb	FG	FLHTCU (I)	Ultra Classic*EFI
BS	FXSTD	Softail Deuce (carb)	FH	FLHPI	Police
BT	FXSTB	Night Train	FK	FLHTCI**	Electra Glide Classic EFI
BV	FXSTI	Standard EFI	FL	FLHTCU (I)	Ultra Classic** EFI
BW	FLSTCI	Heritage Classic EFI	FM	FLHPEI	Police
BX	FLSTFI	Fat Boy EFI	FP	FLTR	Road Glide
BY***	FLSTSI	Heritage Springer EFI	FR	FLHRC (I)	Road King Classic EFI
BY***	FLSTSCI	Heritage Springer Classic EFI	FS	FLTR (I)	Road Glide EFI
BZ	FXSTSI	Springer EFI	FT	FLHPEI	Police
JA	FXSTBI	Night Train EFI	FV	FLHT (I)	Electra Glide Standard EFI
JB	FXST	Softail Deuce EFI	FW	FLHR (I)	Road King** EFI
JD	FLSTNI	Deluxe EFI (Nostalgia)	FX	FLHRS	Road King Custom
JE	FLST	Heritage Softail (Brazil only)	FY	FLHRS (I)	Road King Custom EFI
JG	FLSTFI**	Fat Boy EFI	KA	FLHX	Street Glide carb 2006 only
JH	FLSTCI**	Heritage Classic EFI	KB	FLHX (I)	Street Glide

JJ	FXCW†††	Custom Wide (Softail Rocker)	KE	FLHTK	Electra Glide Ultra Limited
JK	FXCWC†††	Custom Wide (Rocker) Custom	KH	FLTRX	Road Glide Custom
JL	FXSTC	Softail Custom (Twin Cam)	MA	FLHTCUTG	Ultra Tri Glide Trike (2009)
JM	FLSTSB	Softail Cross Bones	MB	FLHXXX	Street Glide Trike (2010)
JN	FLSTFB ‡	Fat Boy Lo (2010)	KG	FLTRU	Road Glide Ultra (2011)
PF	FXSTDSE	S.E. CVO Softail Deuce ‡‡	PA	FLTRSEI	S.E. CVO Road Glide ‡‡
PH	FXSTDSE^2	S.E. CVO Softail Deuce	PC	FLTRSEI^2	S.E. CVO Road Glide
PL	FLSTFSE	S.E. CVO Fat Boy	PV	FLTRSE^3	S.E. CVO Road Glide
PN	FLSTFSE^2	S.E. CVO Fat Boy	PD	FLHRSEI	S.E. CVO Road King
PY	FLSTSE	S.E. CVO Softail Convertible	PG	FLHRSEI^2	S.E. CVO Road King
PY	FLSTSE^2	S.E. CVO Softail Convertible	PG	FLHRSE^3	S.E. CVO Road King
PT	FXSTSSE	S.E. CVO Softail Springer	PG	FLHRSE^4	S.E. CVO Road King
PT	FXSTSSE^2	S.E. CVO Softail Springer	PJ	FLHTCSE	S.E. CVO E-Glide Classic
PT	FXSTSSE^3	S.E. CVO Softail Springer	PK	FLHTCSE^2	S.E. CVO E-Glide Classic
			PR	FLHTCUSE	S.E. CVO Ultra Classic
			PR	FLHTCUSE^2	S.E. CVO Ultra Classic
			PR	FLHTCUSE^3	S.E. CVO Ultra Classic
			PR	FLHTCUSE^4	S.E. CVO Ultra Classic
			PR	FLHTCUSE^5	S.E. CVO Ultra Classic
			PR	FLHTCUSE^6	S.E. CVO Ultra Classic
			PZ	FLHXSE	S.E. CVO Street Glide
			PZ	FLHXSE^2	S.E. CVO Street Glide
			TA	FLTRUSE	S.E. CVO Road Glide Ultra

Dynas					
GD	FXDL	Dyna Low Rider	GT	FXDC	Dyna Super Glide Custom
GE	FXDWG	Dyna Wide Glide	GV	FXDCI	Dyna Super Glide Custom EFI
GG	FXDS-CON	Dyna Convertible	GW	FXD35	Dyna 35th Anniversary EFI††
GH	FXD	Dyna	GX	FXDBI	Dyna Street Bob EFI
GJ	FXDX	Dyna Super Glide Sport	GY	FXDF	Dyna Fat Bob
GL	FXDXT	Dyna Super Glide T-Sport	GP	FXDWG	Dyna Wide Glide (2010)
GM	FXDI	Dyna EFI			
GN	FXDLI	Dyna Low Rider EFI	PB	FXDWG^2	S.E. CVO Dyna Wide Glide ‡‡
GP	FXDWGI	Dyna Wide Glide EFI	PE	FXDWG^3	S.E. CVO Dyna Wide Glide
GR	FXDXI	Dyna Super Glide Sport EFI	PS	FXDSE	S.E. CVO Dyna
GX	FXDB	Dyna Street Bob	PS	FXDSE^2	S.E. CVO Dyna
			PX	FXDFSE	S.E. CVO Dyna Fat Bob
			PX	FXDFSE^2	S.E. CVO Dyna Fat Bob

*with sidecar; also referred to as an FC

**Shrine model

***The early carbureted Heritage Springer's (FLSTS) have a BR designation while BR in later Twin Cam models up to 2006 refers to Heritage Springer Classic (FLSTSC); the early fuel injected Heritage Springer EFI (FLSTSI) has a BY designation while BY in later Twin Cam models refers to Heritage Springer Classic (FLSTSCI).

†FC in early Twin Cams refers to an FLHTCU-I indicating an EFI model. In later years after 2006, all Harley-Davidson's have EFI so the –I is dropped from the model nomenclature. In 2007 and later models FC refers more simply to an FLHTCU. These nuances can drive the novice nuts. Ditto with the FB FLHR Road King, which is EFI because it is a 2007 and later model whereas the FD is an earlier FLHR Road King carbureted model. This stuff occurs all the time. In fairness, H-D working into the future does not know which models will evolve. If working backwards from now to 1903, it would be much easier to organize numbers, letters and designations in a coordinated sequential way.

††FXD35 is the 35th anniversary model. Sound good? Not really because the Dyna first introduced in 1991, 15 years previously. If I subtract 35 from 2006, I get 1971. Well, 1971 is the introductory year for the FX kick-start hybrid between the big FL Electra Glide and the Sportster. So, I guess 2006 is an anniversary of sorts but a big reach to make something special out of a fifteen-year-old model even though there is an FX in the FXD acronym.

††† H-D does something new with the FXST Softail nomenclature. I know, I know, there are almost as many exceptions to the rules as there are rules. The two Rocker models, the FXCW and the FXCWC leave out the ST that traditionally follows the FX on Softail models. The CW acronym stands for Custom Wide, which relates to the massive 240mm rear tire,

which is huge compared to the early Softail rear tire dimensions of a mere 130mm (1 inch = 25.40mm).

‡ The 2010 FLSTFB is called the Fat Boy Lo in the USA but is marketed as the Fat Boy Special in Great Britain (UK).

‡‡ The acronym CVO is for Custom Vehicle Operation. All Screamin' Eagle (S.E.) bikes are CVO models whether they are 1340cc (80c.i), 1450cc (TC88), 1550cc (TC95), 1584cc (103c.i) or 1690cc (110c.i).

Sidecars in Use in Twin Cam Years [1]

GX	1984-2007 varies	TLE sidecar for Touring models
HX	1991-1998 varies	RLE sidecar: Low Riders, Sport Glides, Police
KX	1987-1999 varies	TLE Ultra sidecar
SA	Varies (used back to 1981)	CLE sidecar with FLT
SD	Varies (used back to 1981)	CLE sidecar with FLHT
SE	Varies (used back to 1981)	CLE side car only
SF	Varies	TLE sidecar with FLTC, FLHTC
SG [2]	Varies up to Present [3]	TLE sidecar only (Police) Electra Glide Classic
SH	Varies	CLE Purchased with FLHX
SK [2]	Varies up to Present	TLEU sidecar for Twin Cam FLHTCUI Ultra
SL	Varies up to Present	TLE sidecar for Twin Cam FLHT Standard
SM	Varies up to Present	TLE sidecar for Twin Cam FLHR Road King
SN	Varies up to Present	TLE sidecar for Twin Cam FLHRCI
SP	Varies up to Present	TLE sidecar for Twin Cam FLTRI Road Glide
ST	Varies	TLE sidecar with FLHRSI
SV	Varies up to Present	TLE sidecar for FLHXI Street Glide
FG	1999-2009	FLHTCUI with sidecar

[1] In upcoming Volumes especially Volume VIII: *How it All Works* I will chronicle the whole history of H-D sidecar use, which began in 1915. It is laborious and confusing to do this, as the nomenclature changes around like the wind as does years of usage for different models. Readers familiar with sidecar use may disagree with some of the listings but there is documentation for all I have logged. There is also documentation that contradicts this. Please take this guide as general with plenty of exceptions and differences.

[2] Evolution TLE and RLE plus Twin Cam-to-present TLE and TLEU sidecar primed body assembly (86831-63BDK) harkens back to 1963. From this the reader can discern why some of the confusion exists when there are so many models but the base is over 45-years old.

[3] The SG TLE sidecar had both police use and with the citizen model FLHTC. The deeper one researches, the more confusing nomenclature may become.

CHAPTER XX

Twin Cam Summary

It is easy to criticize Harley-Davidson for the many foibles that occur but one fact is undeniable and that is the product is consistently getting better, offering enhanced bang for the buck with each passing year.

1. The Twin Cam is the best ever Harley-Davidson Big Twin with the possible exception of the V-Rod in terms of reliability, speed and longevity.
2. This platform for the future is just that, a stage to build on.
3. The superlative engine cases are where it all begins. The metallurgy is the best ever used on a Big Twin or Sportster from the inception of Harley-Davidson in 1903.
4. Improved casting and machining technology inspired by design changes take the superb aluminum alloy and pattern it into a firm and exact base that the rest of the engine can draw strength from to rely on for decades.
5. The stronger and very rigid cylinders that sit on and attach to the casings offer hundreds of thousands of miles of potential service directing and supporting the path of the hypereutectic pistons.
6. These high silicon content pistons offer long service intervals absorbing potentially destructive heat. Heat also carries away with the cooling oil squirted up their undersides by oil jets one of many innovations first used with the introduction of the Twin Cam.
7. The piston composition's low expansion rate allows for very close fitment to cylinder walls while slippery Teflon coatings on their skirted thrust surfaces limit wear and very ably assists in break-in when new.
8. The heads continue the themes of rigidity and long service expectancy.
9. The extra finning giving the engine a fatter appearance and hence the engine nickname The Fathead removes heat from the engine and dissipates it into the air.

Predecessor H-D engines contained heat inside the engine. The Twin Cam moves it to the outside explaining why they can be very hot to ride in warmer weather.

1. The single performance boondoggle to the Twin Cam is the head ports air flow capabilities, which are lower than those of the Evolution heads. Some knowledgeable porting a polishing easily rectifies this.
2. The flywheels are better machined than previous counterparts are. Their pressed in massive and hollow oil reservoir cooling crank pin, authoritatively directs the massive connecting rods and their respective pistons.
3. Electronic fuel injection steadily improved from the inadequate system on the Evolutions to the very reliable, sophisticated, and precise one on current models.

The Evolution era presented the first fuel injection on a Harley while the Twin Cam era saw the last carbureted one as increasing emissions dictates effectively and inexorably ban inefficiencies and promotes improved and new technologies.

- The Twin Cam engine developed in response to ever-increasing environmental protection dictates on both the exhaust emissions and noise fronts.
- The noise generated by timing gears that drive the valve train is uncontrollable. The contraction and expansion of the gears create whining sounds when hot and clattering noises when cold.
- Over the years, the Factory used every technology available to manage these sounds but ultimately a design change became the only option.

Noise reduction led to the two-cam design powered by supposedly quieter sprockets and timing chains. Two camshafts are required to keep the basic V-twin look. One traditional camshaft but driven by sprockets and chain would take much more space than meshed gears. This scenario would extend the timing chest up too far, thus destroying the look of the all-important nostalgic marketing formula. The implementation of this design change led to many problems including worn and disintegrating bearings and adjuster pads. This went way beyond normal teething problems. Many new-design timing chest components were introduced in 2006 resolving these issues.

However, the major threat to the continuity of the Twin Cam in its present form is new EPA emissions regulations. Some noxious emissions reduce by 40% in 2010. It is difficult but obviously not impossible for any air-cooled two-cylinder engine with a valve train and the 45^0 -firing patterns peculiar to Harley to meet current standards. However, the end is drawing nigh. Harley riders need to prepare for a liquid cooled engine, overhead cams and a 56^0 or 60^0 degree V-twin at some point in the near future. Did I just describe a V-Rod?

In *Volume II: Performancing the Twin Cam* I take the Twin Cam structural platform and exploit its strengths in the quest for speed. The Twin Cam is the best stage for performancing in the world of Harley Big Twins. One can go for mild to wild horsepower and torque increases in so many ways due to the quality base supporting the enhancements.

I will discuss theory of speed and its practical implementation for carburetion, fuel injection, cams, headwork, strokers, big-bore, supercharging, turbo charging, and nitrous oxide.

It is previously unheard of in the Harley world to build a 124 cubic inch behemoth using the stock engine cases. I will do just that with a comprehensive kit supplied by S&S Cycles. I will chronicle and detail this coast-to-coast riding engine and describe even larger engines from JIMS Machining and R&R Cycles. Less than five years ago, this would have been an impossible quest. This is the biggest complement that one can give this quality platform for rigidity, strength, and reliability.

This is the enduring legacy of the Twin Cam.

I will list the Contents for Volume II: *Performancing the Twin Cam* for the reader's perusal.

Volume II: Performancing the Twin Cam

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Researching Service Recalls for all Years

Acronyms

Biography

Acronyms

# = number
Ω = ohms
0_2 = oxygen as in oxygen sensor
1A = Electra Glide FL-1200
1C = Sportster racing XR-750
1H = FXB Sturgis
2A = Electra Glide FLH-1200
2C = Factory Experimental kick-start: FX-1200
2F = FX Low Rider: FXS-1200
3A = Sportster XLH-900
5A = Servi-Car GE-750
5E = FX Fat Bob: FXEF-1200
6E = FX Fat Bob: FXEF-80
6G = FX Super Glide electric-start: FXE-80
7G = FX Low Rider: FXS-80
8G = XLP Police Sportster: XLP-1000
9D = FX Super Glide electric-start: FXE-1200
A = Alpha (Twin Cam A engines are rubber mounted)
A = amps or amperes (electricity)
ABDC = after bottom dead center
ABS = anti-locking braking system
AC = alternating current
ACC = accessory
ACR = automatic compression release
AEA = Active Exhaust Actuator
AFR = air fuel ratio
AFV = alternate fuel vehicle
AGM = absorbed glass mat (battery technology)
AHDRA = All Harley-Davidson Drag Racing
AKS = anti knock sensor
AMP or amp or amps = amperes (electricity)
aps = average piston speed
AR = anti-reversion also known as tork or torque valves
ARP = Automotive Racing Products (superior hardware fasteners)
ATDC = after top dead center
ATS = air temperature sensor
AVC = automatic volume control
AWG = American wire gauge
B = Beta (Twin Cam B counterbalanced engines)
B = Boron
B+ = battery voltage
B+ = input ECM voltage
BARO = Barometric Pressure
BARO = Barometric Pressure Sensor
BAS = bank angle sensor
BBDC = before top dead center

BCM = Body Control Module
BDC = bottom dead center
bhp = brake horsepower also known as engine horsepower
BTDC = before top dead center
BTU = British Thermal Unit (energy to raise the temp. of 1 pound of water 1 degree F^0).
C = Celsius
C = Chrome i.e. FXCWC
C = Custom i.e FXSTC
c.i = cubic inches
C^0 = Celsius temperature degrees
Ca = Calcium
CA = California
CAL = calibrate
CAL = calibration
CAN = Canada
CAN = Controller Area Network
CARB = California Air Resources Board
CB = Citizens Band Radio
cc = cubic centimeters
CCA = cold cramping amps
CDI = capacitor discharge ignition
CE = check engine lamp
CEL = check engine lamp
cfm = cubic feet per minute
cfm per c.i = the ratio of cubic-feet-per-minute air per cubic inch engine displacement
CKD = Complete Knock Down
CKP = crankshaft position sensor
CLEFI = closed loop EFI
cm = centimeter
CMP = camshaft position sensor, also known as CPK
CNC = computer numerical control, precise and computerized automatic machining
CO = carbon monoxide
CO_2 =carbon dioxide
CPK = camshaft position sensor, also known as CMP
CR = compression ratio
CV = constant velocity
CVO = Custom Vehicle Operation
dB-A = decibel exhaust noise rating
dbhp = drawbar horsepower (used to measure locomotive and farm implement power)
DC = direct current
DD5 = BAKER 5-speed transmission, 1:1 final gear ratio
DD6 = BAKER 6-speed transmission, 1:1 final gear rati0
DD7 = BAKER 7-speed transmission, 1:1 final gear ratio
DFO = Digital Fuel Optimizer also known as TFI
DIN = Deutsches Institut für Normung. Correction factors for dyno measuring.
DIN = Deutsches Institut für Normung. Round wiring connectors for analog audio.
DLC = data link connector
DM = Digital Multimeter
DOM = domestic
DPF = Diesel Particulate Filter

DSPD = digital signal processing dynamometer
DT = Digital Technician
DT I = Digital Technician I
DT II = Digital Technician II
DTC = diagnostic trouble code
DVM =Digital Volt Meter
DVOM = digital volt ohm meter
E = Serial number prefix after year for 61c.i or 1000cc overhead valve engine (began with Knuckle).
EC = exhaust centerline angle
ECM = electronic control module (same as ECU or ICM)
ECT = engine coolant temperature
ECU = electronic control unit (same as ECM or ICM)
ED = exhaust duration
EEC = European Economic Community, the former name of the European Community correction standards brings horsepower figures slightly higher than the SAE.
EEPROM = electrically erasable programmable read only memory
EI = employee involvement
EITMS = engine idle temperature management system (idle temperature cool down)
EMS = engine management system
EPA = Environmental Protection Agency
ESPFI = electronic sequential port fuel injection
ET = elapsed time
ET = engine temperature (usually describes a sensor)
ETC = electric throttle control also known as fly-by-wire
EVAP = Evaporative emissions control system
F = Serial number prefix after year for any Big Twin after initial use designating 1200cc Big Twins
F = Fahrenheit
F^0 = Fahrenheit temperature degrees
F6F = BAKER 6-speed fix (5th gear noise)
F6R = BAKER 6-speed reverse
FL = police model Panhead or Shovelhead
fl oz = fluid ounce
FLH = citizen model Panhead or Shovelhead
FLHPI = Road King Police EFI
FLHR = Road King carbureted
FLHRCI = Road King Classic with EFI
FLHRI = Road King EFI
FLHRPI = Road King Police EFI
FLHRS = Road King Custom
FLHRSE^3 = S.E. CVO Road King
FLHRSE^4 = S.E. CVO Road King
FLHRSEI = S.E. CVO Road King
FLHRSEI^2 = S.E. CVO Road King
FLHRSI = Road King Custom EFI
FLHS = Electric Glide Sport
FLHT = Electra Glide
FLHT = Electra Glide Standard
FLHTC = Electra Glide Classic

FLHTCI = Electra Glide Classic EFI
FLHTCSE = S.E. CVO E-Glide Classic
FLHTCSE^2 = S.E. CVO E-Glide Classic
FLHTCU = Ultra Classic Electra Glide
FLHTCUI = Ultra Classic Electra Glide EFI
FLHTCUSE = S.E. CVO Ultra Classic
FLHTCUSE^2 = S.E. CVO Ultra Classic
FLHTCUSE^3 = S.E. CVO Ultra Classic
FLHTCUSE^4 = S.E. CVO Ultra Classic
FLHTCUSE^5 = S.E. CVO Ultra Classic
FLHTCUSE^6 = S.E. CVO Ultra Classic (2011)
FLHTCUTG = Tri Glide Ultra Classic
FLHTCUTG = Ultra Tri Glide Trike (2009)
FLHTI = Electra Glide Standard EFI
FLHTK = Electra Glide Ultra Limited (2010)
FLHTP = Electra Glide Police
FLHTPI = Electra Glide Police EFI
FLHX = Street Glide
FLHXI = Street Glide EFI
FLHXSE = S.E. CVO Street Glide
FLHXSE^2 = S.E. CVO Street Glide (2011)
FLHXXX = Street Glide Trike (2010)
FLST = Heritage Softail
FLSTC = Heritage Special (Classic) Softail
FLSTCI = Heritage Classic EFI
FLSTCI = Heritage Classic EFI
FLSTF = Softail Fat Boy
FLSTFB = Fat Boy Lo
FLSTFB = Fat Boy Lo (Fat Boy Special)
FLSTFI = Softail Fatboy EFI
FLSTFSE = S.E. CVO Softail Fat Boy
FLSTFSE^2 = S.E. CVO Softail Fat Boy
FLSTN = Deluxe (Nostalgia)
FLSTN = Heritage Softail Nostalgia Limited Edition aka Moo Glide
FLSTN = Heritage Softail Special
FLSTN = Softail Deluxe
FLSTNI = Softail Deluxe EFI (Nostalgia)
FLSTS = Heritage Springer
FLSTSB = Softail Cross Bones
FLSTSC = Heritage Springer Classic
FLSTSCI = Heritage Springer Classic EFI
FLSTSE = S.E. CVO Softail Convertible (2010)
FLSTSE^2 = S.E. CVO Softail Convertible (2011)
FLSTSI = Heritage Springer EFI
FLTC = Tour Glide Classic
FLTCU = Ultra Classic Tour Glide
FLTCUI = Ultra Classic Tour Glide EFI
FLTR = Road Glide
FLTRI = Road Glide EFI

FLTRSE^3 = S.E. CVO Road Glide (EFI or I dropped from nomenclature in later years after 2007)
FLTRSEI = S.E. CVO Road Glide
FLTRSEI^2 = S.E. CVO Road Glide
FLTRU = Road Glide Ultra
FLTRUSE = S.E. CVO Road Glide Ultra (2011)
FLTRX = Road Glide Custom
FMS = fuel management system
FP = fuel pump
fpm = feet per minute
FRS = Family Radio Service
ft/s = feet per second
FX = kick start Shovelhead Big Twin sport model 1972 up
FXCW = Custom Wide (Softail Rocker)
FXCWC Custom Wide (Softail Rocker) Custom
FXD = Dyna Super Glide
FXD35 = Dyna 35th Anniversary EFI
FXDB = Dyna Glide Sturgis
FXDB = Dyna Street Bob (EFI or I dropped from nomenclature in later years after 2007)
FXDB-D = Dyna Glide Daytona
FXDBI = Dyna Street Bob EFI
FXDB-S = Dyna Glide Sturgis
FXDC = Dyna Glide Custom
FXDC = Dyna Super Glide Custom
FXDCI = Dyna Super Glide Custom EFI
FXDF = Dyna Fat Bob
FXDFSE = S.E. CVO Dyna Fat Bob
FXDFSE^2 = S.E. CVO Dyna Fat Bob
FXDI = Dyna Super Glide EFI
FXDL = Dyna Low Rider
FXDLI = Dyna Low Rider EFI
FXDS = Dyna Low Rider
FXDS-CONV = Dyna Low Rider Convertible
FXDSE = S.E. CVO Dyna Super Glide
FXDSE^2 = S.E. CVO Dyna Super Glide
FXDWG = Dyna Wide Glide
FXDWG = Dyna Wide Glide (2010) new version
FXDWGI = Dyna Wide Glide EFI
FXDWGSE = S.E. CVO Dyna Wide Glide
FXDWGSE^2 = S.E. CVO Dyna Wide Glide
FXDWGSE^3 = S.E. CVO Dyna Wide Glide
FXDX = Dyna Super Glide Sport
FXDXI = Dyna Super Glide Sport EFI
FXDXT = Dyna Super Glide T-Sport
FXE = electric start Shovelhead Big Twin sport model 1973 up
FXLR = FXR Low Rider Custom
FXR = FXR Super Glide.
FXR = rubbermounted, electric start Shovelhead or Evolution sport model 1982 -1994
FXR^2 = 1999 Evolution CVO Screamin' Eagle
FXR^3 = 1999 Evolution CVO Screamin' Eagle

FXR^4 = 2000 Evolution CVO Screamin' Eagle
FXRC = FXR Low Glide Custom
FXRD = FXR Sport Glide Grand Touring
FXRDG = FXR Disc Glide
FXRP = FXR Police
FXRS-CONV = FXR Low Glide/Low Rider Convertible
FXRSDG = FXR Disc Glide
FXRS-SP = FXR Low Rider Sport
FXST = Softail
FXST = Softail Standard
FXSTB = Softail Night Train
FXSTBI = Softail Night Train EFI
FXSTC = Softail Custom
FXSTD = Softail Deuce
FXSTDI = Softail Deuce EFI
FXSTDSE = S.E. CVO Softail Deuce
FXSTDSE^2 = S.E. CVO Softail Deuce
FXSTI = Softail Standard EFI
FXSTS = Softail Springer
FXSTSB = Softail Bad Boy
FXSTSI = Softail Springer EFI
FXSTSSE = S.E. CVO Softail Springer
FXSTSSE^2 = S.E. CVO Softail Springer
FXSTSSE^3 = S.E. CVO Softail Springer
g = gram
gal = gallon
GAWR = gross axle rate rating
GDP = gross domestic product
GMRS = General Mobile Radio Service
GND = ground
gpm = gallons per minute
GUI = graphical user interface
HC = hydrocarbons
HCR = high contact ratio (gear teeth)
HCU = hydraulic control unit
H-D = Harley-Davidson
HDI = Harley-Davidson International
HDLAN = Harley-Davidson Local Area Network
HDMOCO = Harley-Davidson Motor Company
HDMoco = Harley-Davidson Motor Company
HDOA = H-D Owners Association
H-DSSS = Harley-Davidson smart security system
HFSM = hands free security module
Hg = Mercury
HOG = Harley Owners Group
HP = horsepower
hp/kg = horsepower per kilogram; see also watts/hp, kw/hp and hp/lb (power-to-weight ratio)
hp/lb = horsepower per pound; see also hp/kg, kw/hp and watts/hp (power-to-weight ratio)

HTCC = High Torque Combustion Chamber
HTHS = high temperature/high shear rate viscosity
Hz = Hertz
IAC = idle air control
IAT = intake air temperature (usually describes a sensor)
IC = intake centerline angle
IC = integrated circuit
ICM = ignition control module (same as ECM or ECU)
ID = inside diameter
ID = intake duration
IDLE TRIM = position of ISC (idle speed control) actuator at rest
IDLE/WOT = throttle sensor range
IDS = Isolated Drive System (rubber mount rear drive pulley)
IGN = ignition switch (ign)
Ihp = indicated horsepower
ILSAC = International Lubricant Standardization Approval Committee
IM = instrument module
In = inch
INJ PW = injector pulse width (milliseconds)
in-lbs = inch-pounds
IOC = inlet-over-exhaust; overhead suction intake valve and an exhaust sidevalve F-Head
ISC = idle speed control (MM EFI)
ISC POS = Position of Idle Speed Control
IST = intelligent spark technology (S&S ignition)
ITC = International Trade Commission
J = joule (a joule is the mechanical equivalent of heat).
JIS = Japanese Industrial Standards. Correction factors for dyno measuring standardization in Japan, adjust horsepower figures slightly higher than the SAE.
JIT = just in time inventory
k = kilometer
K = kilometer
k = thousand (1000 meters in a kilometer)
k/hr = kilometers per hour
kg = kilogram (2.2lbs)
kgf.m/s = kilogram-force meters per second
km = kilometer
km/hr = kilometers per hour
kNm^2 = metric pressure measurement equivalent to psi
kPa = kilopascal
kw/hp = kilowatts per horsepower; see also watts/hp hp/kg and hp/lb; (power-to-weight ratio). 1 horsepower equals .7457 kilowatts
l = liter
L/R = connecting rod length divided by the engine's stroke length
LC = lobe centerline angle
LCA = lobe centerline angle
LCD = liquid crystal display
LED = light emitting diode
LSA = lobe separation angle
m = meter
m/s = meters per second

mA = milliampere (1/1000th of an amp or ampere)
MAN = material as needed
MAP = manifold absolute pressure (usually a MAP sensor measures manifold vacuum)
MCR = mechanical compression release
Mg = Magnesium
MHz = megahertz, 10^6 Hertz (Hz)
ml = milliliter
MLS = multi layer system; refers to multi-layered gaskets
MM = Magneti-Marelli electronic fuel injection used from 1995 to circa 2001-2002.
mm = millimeter
Mo = Molybdenum
MOCO = Motor Company, a colloquialism for Harley-Davidson
Moco = Motor Company, a colloquialism for Harley-Davidson
mph = miles per hour
mps = mean piston speed
ms = millisecond
MSO = Manufacturer's Statement of Origin
MTBE = methyl tertiary-butyl ether ($C_5H_{12}O$) a gasoline oxygenate (octane) additive
MURS = Multiple-Use Radio Service
MY = mid-year
N/A = not applicable
NA = not applicable
Na = Sodium
nhp = nominal horsepower (inaccurate and out-of-date)
NLGI = National Lubricating Grease Institute
Nm = Newton-meter (Sir Isaac Newton), a metric unit of torque
No = number
NO_x = nitrogen oxides
O = ohm (electrical)
od = outside diameter (also OD)
OD6 = BAKER 6-speed overdrive transmission
OD6-Z 0.86 = BAKER 6-speed overdrive transmission; 0.86 final gear ratio
OEM = Original Equipment Manufacturer (stock parts)
OHC = overhead cams (V-Rod has overhead cams)
OHV = overhead valves (all Big Twins and Sportsters have overhead valves)
OLEFI = open loop EFI
oz = ounce
P = Phosphorus
P&A = parts and accessories
P&P = porting and polishing
Pb = lead
PC = Power Commander
PCI = Power Commander I (1st generation)
PCII = Power Commander III (2nd generation)
PCIII = Power Commander III (3rd generation)
PDA = personal digital assistant (handheld computer)
PHD = H-D technician training at Harley University (professional Harley-Davidson)
Pi = Pi or π is a mathematical constant; 3.14159. It represents the ratio of a circle's area to the square of its radius.
PN = part number (pn)

psi = pounds per square inch
pt = point (as in 12-point or 12pt hardware fastener)
PTT = push to talk (Ultra rear speaker volume switch)
R&D = research and development
RA = roughness average, micro-inch measurement of a surface finish like a gasket surface.
RES = reserve
RFG = reformulated gasoline
RFI = radio frequency interference
rpm = revolutions per minute
RSD = right side drive (transmission for big rear tires)
S = Sulphur
S&S = S&S Cycle, Inc.
S.E. = Screamin' Eagle
SAE = oil viscosity ratings by the Society of Automotive Engineers
SAE = Society of Automotive Engineers (correction factors for dyno measuring standardization in USA/Canada since 1990)
SAPS = Sulphated Ash, Phosphorus, Sulphur (relates to catalytic friendly engine oil)
SCFH = cubic feet per hour at standard conditions
SCR = silicone controlled rectifier or regulator
SE = Screamin' Eagle
SERT = Screamin' Eagle Race Tuner
SI = International System of Units
SOC = statistical operator control standardization in Germany, adjust horsepower figures slightly higher than the SAE.
STD = same as STP. Correction factors for dyno measuring standardization in USA/Canada before 1990, adjust horsepower figures slightly higher than the SAE.
STP = same as STD. Correction factors for dyno measuring standardization in USA/Canada before 1990, adjust horsepower figures slightly higher than the SAE.
SV = side valve Flathead (Sidevalve)
SWR = Standing Wave Radio (meter)
TB5 = BAKER 5-speed torque box transmission
TB6 = BAKER 6-speed torque box transmission
TCA = throttle control actuator
TDC = top dead center
TDCO = top dead center offset
TFI = Techlusion Fuel Injection also known as DFO
TGS = twist grip sensor
thp = true horsepower also known as rear wheel (whp) or effective horsepower
TMAP = intake air temperature/manifold absolute pressure
TP = throttle position
TPS = throttle position sensor
TSM = turn signal module
TSSM = turn signal/security module
TT = Tech Tip (H-D vernacular for circulars that it sends out to its service people)
TÜV = European Community standards (similar but different from EPA)
TV = Terminal Velocity (EFI fuel modifier)
TWC = three way catalyst
US gal/m = U.S. gallons per minute
V = volt
V/P = volume to pressure index (monitors volume of air/gas relative to compression ratio)

V^2 = Evolution
VAC = volts of alternating current
VDC = volts of direct current (vdc)
VE = volumetric efficiency (usually refers to amount of cylinder fill)
VFI = variable fuel ignition (S&S EFI)
VIN = vehicle identification number. H-D registers by the frame VIN since 1970 and the engine VIN for 1969 and earlier.
VO= valve overlap
VOES = vacuum operated electric switch
VOVS = vacuum-operated valve switch
VRLA = valve-regulated lead-acid battery
VRSCA = V-Rod Street Custom 1130cc
VRSCAW = V-Rod Wide Tire
VRSCB = V-Rod (black frame)
VRSCD = Night Rod
VRSCDX = Night Rod Special
VRSCF = V-Rod Muscle
VRSCR = V-Rod Roadster (Street Rod)
VRSCSE = S.E. CVO V-Rod Custom 1250cc
VRSCSE^2 = S.E. CVO V-Rod Custom 1250cc
VRSCXSE = S.E. CVO V-Rod Destroyer 1300cc
VSS = vehicle speed sensor
W = watts (electricity)
watts/hp = watts per horsepower; see also kw/hp, hp/kg and hp/lb; (power-to-weight ratio) 1 horsepower equals 745.7 watts.
WEGO I = Wide-band Exhaust Gas Oxygen: first generation (Daytona Twin Tec tuner)
WEGO II = Wide-band Exhaust Gas Oxygen: second generation (Daytona Twin Tec tuner)
WEGO III = Wide-band Exhaust Gas Oxygen: third generation (Daytona Twin Tec tuner)
whp = wheel horsepower or rear wheel, true (thp), or effective horsepower
WO2 = wideband oxygen sensor
XL = Experimental Lightweight (Sportster)
XL1200C = 1200cc Sportster Custom
XL1200L = 1200cc Sportster Low (lowered)
XL1200N = 1200cc Sportster Nightster
XL1200R = 1200cc Roadster
XL1200S = 1200cc XL Sport (Sportster)
XL5 = BAKER Sportster 5-speed
XL6 = BAKER Sportster 6-speed
XL883C = 883cc Sportster Custom
XL883L = 883cc Low (lowered)
XL883N = 883cc Sportster Iron
XL883R = 883cc Sportster with racing graphics
XLA = Army Sportster
XLCH = Competition Hot (Factory equipped with hi-performance options) Sportster
XLCR = Café Racer (Sportster)
XLH = high compression XL (1958) Sportster
XLH1100 = 1986 1100cc (1st year)
XLH1200 = 1988 (1st year)

XLH883 = 1986 883cc (1st year)
XLS = Roadster XL Sportster
XLT = Touring Sportster
XLX = Economy Sportster or stripped down XL
XR1000 = 1000cc Sportster street legal
XR1200 = 1200cc Sportster (2010)
XR1200 = 1200cc Sportster export only (2008-2009)
XR1200 = 1200cc Sportster XR (racing)
XR1200X = 1200cc Sportster (2010)
XR750 = 750cc Sportster – off road only (racing)
ZDDP = zinc dialkyl dithiosphosphate anti-wear agent in modern oil
ZF = zinc-free (anti-wear additives for oil)
Zn = Zinc
π = Pi is a mathematical constant; 3.14159. It represents the ratio of a circle's area to the square of its radius.

Author Biography

When the Nazis' invaded my parent's homeland, Denmark during WWII, both immigrated to Canada, joined the Royal Canadian Air Force, and became commissioned officers by war's end.

Enrolled in an inner city school as a child, wearing European britches and knee socks was not a pleasant experience. After many beatings, I began to learn how to fight or rather the need to fight.

Trying to fulfill every immigrant parent's dream for the first born, I was not allowed to go to technical schools and wound up at Brock University (college) and later York University, in Toronto Canada, studying Town Planning. After three years of post secondary school education, I surveyed my class of 300 realizing that only six jobs existed at the time for this occupation across Canada.

I decided to pursue Social Work, which I had been doing part time as an outreach youth worker with the YMCA. Working with street gangs in Toronto's toughest housing projects *on the streets, at night* was always interesting and sometimes dangerous.

During this time, I purchased my second Harley, a 1966 Shovelhead. I began to work on this bike. I found this very satisfying, as there is a cause for every effect and vice versa. This was much easier than fixing the problems of wayward youth.

With the early Seventies advent of psychedelic drugs, I was thrust into crisis intervention on the streets having to deal with bummers, bad trips, freak-outs and overdoses and all that went with them. Outreach workers were way ahead of the curve as society tried to grapple with this new counter culture. I helped form the first non-counter culture, street-level counseling center in Ontario under the auspices of the Drug Addiction Foundation and the YMCA. My first teaching experiences followed with parents groups, social workers, and psychiatrists.

I enjoyed watching the early biker movies but when *Easy Rider* premiered; my course in life became set. Soon after, I proudly finished my first chopper, a day-glow painted, radically raked, twelve inch extended wide glide with no front fender or brake and ape hanger handlebars.

The same summer while riding, I was center-punched by a car in an intersection, breaking my back and leg in over a hundred places. A medical journal documented my miraculous recovery after I refused to have my leg amputated at the hip. Doctors felt this necessary because of a crushed femur and a mostly severed main nerve before the advent of microsurgery. Lying in traction for months without being able to move as blood clots traveled my body settling in my legs and lungs taught me my his most prized life skill. The options were going crazy or developing a strong disciplined mind. I developed the mind and became a heavy weight lifter years later, when able, to develop the body.

On crutches, with a 1959 Panhead, replete with suicide clutch and hand shift, I began my 38-year membership sequentially in two prominent motorcycle clubs. Sometimes it is not easy being a little different in a homogenous world.

Circa 1972, the urge to become entrepreneurial overcame me. I worked out of back alley garages in Toronto's downtown tenderloin before formally starting Heavy Duty Cycles in 1974. In 1977, I became a licensed mechanic. Post secondary school physics, taken many years before, came into play. Physics allowed me to understand and develop hi-performance concepts, which helped immensely in the business. Those school essays also taught me how to write…although, not how to adhere to all the rules of the publishing world.

Living on the streets as well as in academia in addition to a blue-collar trade gave me interesting perspectives on life.

As my businesses developed, a manufacturing stint in the Orient made me realize that I loved to travel, which has become my main passion other than motorcycling.

I became a tech writer in 1989. The articles have worldwide readership. This in turn has given Heavy Duty Cycles international stature.

My motorcycles, many hand fabricated, have been featured in publications from Great Britain, France, Japan and Russia as well as closer to home in magazines such as Easyriders, VQ, American Iron, Hot Bike and Canadian Biker. I was first titled as a "Master Builder" by Supercycle Magazine in the 1980's and then awarded this status by VQ and Easyriders Magazines but I am the first to acknowledge that no one person can fabricate the bikes that Heavy Duty Team always aspires to. It requires a team effort by the industry's best and I confer this honor on the *Team* of which I am only a part.

The Canadian Government invited me to teach the Havana Harley Riders Club at the Embassy in Cuba as a goodwill gesture to the Cuban people in 1997 looking forward to a post-Castro democracy.

I began to teach every apprentice motorcycle mechanic in Ontario, Canada before they were able to test for their mechanics license. I then became involved with the Federal Government and the Provinces in updating and standardizing these courses for the whole country. I followed up by assisting in writing the final computer generated Mechanics Examination utilized across Canada in order to produce mechanics with a standard respected worldwide.

Finally, I was invited by the Provincial government to join a committee advising the Minister of Education on the implementation of an apprenticeship program for young people entering the various trades. In my third year, I was elected Chairperson of this committee. My first recommendation was accepted and implemented by the Ministry.

Then my abrupt dismissal by the Deputy Minister of Education happened on a Friday evening. Apparently, my membership in my motorcycle club was to be brought up in the legislature to embarrass the sitting government. It mattered not that I voluntarily served the government with skill, honesty, and integrity.

Over the years, I with committed friends spearheaded many bikers' rights initiatives, mostly to no avail. One constitutional challenge to Canada's Supreme Court led to another honor that of being invited to speak to the prestigious Empire Club in Toronto's Royal York Hotel. Fellow speakers over the years included George Bush Sr., Ronald Reagan, Billy Graham, Dalai Lama, and Queen Elizabeth. My invitation distinguished me as one of the few no-name speakers.

An avid scuba diver, my first open water dive was in the South China Sea off the coast of Borneo looking for whale sharks.

Other hobbies include mountain trekking. I have trekked Peru's Inca trail from the center of the Incan empire in Cuzco in the Andes to Machu Pichu. I then climbed Africa's highest mountain, Kilimanjaro.

In my next venture climbing Mount Everest in Nepal, I contracted both forms of the deadly acute mountain sickness as well as curable but still lethal Dysentery. With literally only hours to live before falling asleep into a coma and succumbing, the climb down increasingly supplied more oxygen and temporarily stayed the death sentence. Lower altitude is the only cure. With the help of my wife at the time, I had to summon all my will power gained during my bike accident years before, to make my way down the mountain for two days to get to a lower altitude for a possible rescue attempt. Helicopters and small planes can only fly at altitudes less than 15,000 feet.

We saved another climber's life on the way. At the lower altitude, the three-day rescue off Mt. Everest by Sir Edmund Hillary's personal pilot is a high point in my life. The helicopter almost crashed because of big rocks inside the clouds during the flight back to Katmandu. It still was not quite over as weather forced the helicopter down into a gorge for a night interrupting the very dangerous flight.

I have tried my hand as an adventure travel writer but not met with much achievement. However, my bike trips across North and South America, Europe and most recently South Africa have led to many motorcycle travel articles that are enjoying some success.

Millions of viewers have enjoyed mine and Tattoo Tony's technical segments on Canada's serial motorcycle show Biker TV as well as our appearances on The History of the Chopper. Authorities, upset at my motorcycle club membership pressured the show, its producer, and advertisers to the point of my being discontinued. However, my first love was working with my customers at Heavy Duty Cycles where I look forward to every day.

Then authorities began the process to revoke my various business licenses even though I had neither a criminal record nor one customer complaint to regulating bodies in my 36-years in business. I was forced to sell Heavy Duty Cycles to Tattoo Tony in 2009.

I have no children in spite of three marriages and divorces. I take onus for all three separations hesitating to call them failures. I view them as passing ships in life.

Paradoxically, I have taken up the sweet science of boxing at age 61, which I find very fulfilling. I have great fun with the much younger boxers, some less than a third or of my age that cannot figure out the *old guy* who hits back. I view the training required for boxing as the fountain of youth that will add ten years to any practitioner's life. It teaches coordination, flexibility, balance, speed, and endurance…and yes, after much practice it is possible to defend oneself with ease.

What is the future?

I will finish my twelve volumes of *"Donny's Unauthorized Technical Guide to Harley Davidson 1936-Present.*

I will go into the ring. The endurance, defensive skills, and lastly offence required combined with the mental ability to overcome extreme pressure to engage opponents of skill is something one must experience to understand. Anyone stepping through those ropes is a warrior.

I want to revisit Everest.

I will ride my Harleys.

I will remarry in a few years or maybe not.

Moreover, I am currently planning to take the time after my current legal battles to walk the medieval pilgrim's trek from France through northern Spain.

I may relocate to the Pacific coast in Mexico to write, ride and drink some cold beer. Of course, the workaholic will need to start a business also to keep me occupied.

However, after dealing with a very expensive months-long Preliminary Hearing, similar to a Grand Jury to see if there was evidence to take me to trial for my membership position in my bike club, I was committed for trial because of my personal belief system of being a man. I appealed to no avail. I have begun a lengthy and arduous trial process in September 2010 that will hopefully be over in August 2011. A targeted person in the judicial system is punished severely before a finding of innocence or guilt. There is a court imposed publication ban on this hearing so nothing else can be said at this point. Who does this protect? Surely, not me… let the chips fall where they may!

Hopefully by the time Volume V: *The Sportster: 1952 to Present* goes to print, I will be able to talk about this persecution; oops, sorry that was a Freudian slip for prosecution.

They try to take every form of creative endeavor I engage in, but they can never take my writing from me. Hopefully, the pen proves stronger than the sword.

LaVergne, TN USA
21 March 2011

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TRANSPORTATION

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DONNY PETERSEN is the founder and operator of Heavy Duty Cycles in Toronto, Canada. His monthly column, Techline, has appeared in *American Iron Magazine* since 1992. Instructed privately by Harley-Davidson engineers, he has taught mechanics, designed tech-school curricula, and authored student-licensing examinations. A Toronto resident, Petersen hosts *Tech-Talk* on Biker TV.

U.S. $38.95

ISBN 978-1-4

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www.iuniverse.com

P9-BGE-567